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DY OF THE EFFECTIVENESS OF REDUCED VISIBILITY GUIDANCE TECHNIQUES

Vol. II. Equipment Survey

DEPARTMENT OF
TRANSPORTATION
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February 1979
Final Report

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Prepared for
FEDERAL HIGHWAY ADMINISTRATION
Offices of Research & Development
Washington, D. C. 20590

FOREWORD

This report contains an equipment survey performed as part of a research study to evaluate the effectiveness of various techniques for guiding motorists during reduced visibility conditions. The report will be of interest to traffic engineers concerned with problems caused by adverse weather conditions.

As a result of this research, a methodology was developed to assist highway engineers in allocating resources in a systematic way based on specific local highway and weather situations. The methodology is available in FHWA Implementation Package 79-2, "User Guidelines for Reduced Visibility System Design."

Research in reduced visibility guidance techniques is included in the Federally Coordinated Program of Highway Research and Development as Task 4, Project 1L, "Improved Traffic Operations During Adverse Environmental Conditions." Mr. Richard N. Schwab is the Project Manager.

Single copies of the report are available on request.

Charles F. Scheffey
Director, Office of Research
Federal Highway Administration

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A study was performed to evaluate the effectiveness of reduced visibility guidance systems and operating strategies; and determine, if possible, which factors of system design contributed to system effectiveness and which approach is economically feasible for a specific highway condition. Data were assembled and analyzed from seven existing reduced visibility systems. A utility/cost model was generated which permits quantitative comparisons to be made between systems. A "measure of need" index was generated to make comparisons between the seriousness of the hazard at different locations.

The study resulted in a methodology which allows a reduced visibility problem to be quantified and permits resources to be allocated in a systematic way in proportion to the seriousness of the hazard.

The methodology itself has been published by the FHWA as Implementation Package Number 79-2.

This volume consists of the Equipment Survey, which is the second of a two volume Final Report series. The first volume is the Final Report itself, identified by the following number.

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Section 1
INTRODUCTION

1-1 SCOPE OF SURVEY

This survey, which is the second volume in a two volume report on reduced visibility guidance (RVG) systems, covers equipment in five categories commonly found in RVG systems.

- Fog Sensors and Monitors, employing transmission, backscatter, forward scatter, total scatter, and optical contrast techniques, as well as closed circuit television (CCTV) techniques
- Vehicle Sensors, including loop, magnetic and magnetometer types
- Signing, including fixed message, blankout and variable message signs using lamp matrix, neon, disc matrix, rotating drum displays
- Reduced Visibility Guidance and Delineation, passive and active roadway delineation devices such as thermoplastic striping, post delineators, raised pavement markers, pavement inset lights, and strobe lights.
- Communications Equipment, including cable, radio, and microwave techniques. This category also includes roadside radio (HAR) aids.

1-2 SURVEY OBJECTIVES

The objectives of the equipment survey are to develop a framework within which various approaches to satisfying the needs of RVG systems may be compared and evaluated. Specifically, the objectives are to document for system planners the technological background, state-of-the-art, costs, and user experience of the equipment described in this report.

This survey was completed in February 1977. Naturally, since technology, state-of-art and costs occur rapidly as time progresses, the reader should be aware that significant changes could have taken place between the time this survey was finished and its subsequent final publication date.

Section 2
VISIBILITY DETECTORS

2-1 INTRODUCTION

The purpose of this survey is to determine availability and cost of equipment applicable to an RVG system, and to identify and compile results of any evaluations of equipment currently used in RVG systems. The survey was conducted through telephone contacts and correspondence with manufacturers and distributors of the equipment identified in prior studies and uncovered through the literature search, and by contact with principal users and researchers in the field. Manufacturers' names and addresses are listed in Appendix G.

2-2 VISIBILITY DETECTION AND MEASUREMENT EQUIPMENT

Appendix A summarizes the currently available visibility equipment. Some equipment identified in previous studies is no longer available and some new devices are on the market. A summary of the technical capability and a brief evaluation of each of the equipments listed in Appendix A are given by manufacturer/distributor in alphabetical order.

a. AEG TELEFUNKEN

Allgemeine Elektricitäts-Gesellschaft of West Germany has developed in conjunction with Flugwissenschaftliche Forschungsanstalt of Munich a new fog detector being marketed as AEG/FMM Scattered Light Recorder. The principle of operation is the measurement of light scattered from a small volume illuminated by a flash lamp through angles from ten to 120 degrees thereby approximating the total scatter function. Rated accuracy is five percent of threshold value with a five percent error of linearity. It has a two decade measurement range and consumes 200 w including heater. The lamp is rated at one year life.

b. AERAZUR CONSTRUCTIONS ELECTRONIQUES

The Aerazur company manufactures a transmissometer unit called Helios in four versions. The basic measuring instrument is identical in all four versions, with various accessory packages depending on the data transmission and recording requirements. While originally intended mainly for airport use, it has been used for visibility measurement and speed control on at least one highway in France. No price or operating cost information is available at this time.

c. SATT ELEKTRONIK AB

The AGA/SATT FD-300 Fog Detector is a backscatter device developed for marine use. It is lightweight and compact (55.1 lbs, 25 kg) and makes use of a GaAs light-emitting diode. The measurement range is 0.1 to 9.9 nautical miles (0.18 km to 18.1 km) visibility with an adjustable fog signal threshold. Power consumption is 7 w peak (0.5 w average) at 12 vdc. The output power is 50 mw at a pulse frequency of 15 kHz. It is designed to operate over a temperature range of -40° F to 158° F (-40° C to 70° C). No heaters are required, and the manufacturer claims that self compensation for dirt on the optics is provided. No test results are available at this time. The price is $9,000 fob Toronto with the addition of 15 to 20 percent duty. Operating costs are not available; however, the all solid state construction suggests low maintenance. Installation costs are low as with all backscatter devices.

d. ASEA

ASEA is known internationally for its GaAs ceilometer. They have also developed a GaAs backscatter fog detector. Because of the high reputation of ASEA, mention is being made of this device although no technical data are available as yet.

e. ATELIERS DE CONSTRUCTIONS ELECTRIQUES DE CHALEROI

The Videometer is basically a closed circuit TV (CCTV) system used to observe light sources at known distances. Developed in collaboration with the Belgian Air Ministry, it is intended for measurement of Runway Visual Range. No price or maintenance information is available. It was tested at the Brussels airport and the University of California fog chamber.*

This system has not found widespread use, probably due to problems of linearity of response inherent in the vidicon tubes of the time. No technical data are available as yet.

f. B.E.L. DEVELOPMENTS, LIMITED

The Transport and Road Research Laboratory (TRRL) developed the TRRL Fog Detector for highway use. It is basically a folded transmissometer which is compact, portable, and devoid of installation and alignment problems associated with larger airport type devices. It measures the attenuation of a pulse of red light over a path length of 13.1 feet (4 m). The measurement range is 32.8 to 1,312 feet (10 m to 400 m) in the visual range and the device is reported by TRRL to be tolerant of dirty roadside conditions, automobile headlights, and vibrations. Three TRRL Fog Detectors have been undergoing highway testing since 1974 with results monitored by the UK Meteorological Office. Results were positive and the device is now being manufactured. The price is £ 1650 fob (15 to 20 percent duty additional) while maintenance and operating costs are stated by the manufacturer to be minimal. Delivery time is eight to ten weeks from receipt of order.

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*Videometer, New Device for the Measurement of Runway Visual Range, Belgian Airport and Airways Agency, Brussels, 1966; Tests on ACEC Videometer in Fog Chamber at University of California, Berkeley, CA USA; Report No. FAA-RD-67-32, Final Report, July 1967.

g. COLORADO ELECTRO-OPTICS

The Highway Safety Fog Detector, Model 172B is a transmissometer developed for highway use; however, because it is not a compact folded system as above, it requires a slightly more sophisticated installation. Because of broad beam divergence, the manufacturer claims that alignment is not critical. The transmitter uses pulsed GaAs and the electronics are all solid state. Heaters provide automatic defrosting and defogging of the optics. The baseline can be set from 250 to 1,000 feet (76.2 m to 304.8 m) with a measurement range of from 200 to 2,000 feet (61 m to 610 m) in the visual range at a 300 foot (91.4 m) baseline. It is designed for a temperature range of -30° F to 130° F (-34° C to 54° C) and has multiple independently-adjustable alarm thresholds. Power requirements are 100 w at 110 v. Price with one alarm relay is $2,900 fob. Maintenance costs are low, according to the manufacturer. No test results are available.

h. EG&G, ENVIRONMENTAL EQUIPMENT DIVISION

Development of the FSM (Forward Scatter Meter) was supported by the Air Force and testing has been extensive. Measurement of forward scatter (about 30° to the forward direction) is the best approximation to transmission (the basis of visibility) according to scattering theory and has been verified by these tests. Under homogeneous conditions, the FSM tracks a standard transmissometer accurately (e.g., see Field Test of a Forward Scatter Visibility Meter, Air Force Cambridge Research Laboratory, AFCRL 71-0315, May 1972). It is a single unit for ease of installation; however it is somewhat heavy and bulky, having a weight of 135 lbs. (61.2 kg) and a length of four feet (1.2 m). An incandescent light source is modulated at 292 Hz to reduce background via synchronous detection and the output is maintained constant through electronic feedback. The electronic construction is all solid state. The measurement range is 200 to 20,000 feet (61 m to 6,096 m) in the visual range with five percent accuracy in the scattering coefficient. Power consumption is 200 w at 115 v, and it is designed to operate over a temperature range of -22° F to 122° F (-30° C to 50° C). Current price is $9,800 fob, with a calibrator priced at $1,800. The manufacturer claims a Mean Time Before Failure (MTBF) of one year, the major difficulty being motor bearings which require 0.5 man-day per year to replace. (A mechanical light chopper is used to modulate the light.) Routine optics cleaning is advisable as with any optical device operating in a hostile environment.

i. ELTRO GMBH

The Eltro GmbH No. 8 transmissometer is a dual baseline folded transmissometer. It consists of two projectors side-by-side and two reflectors removed by 49.2 and 492 feet (15 m and 150 m) respectively. One light source is used as both a measuring and a reference source. The measurement and reference beams are alternately sampled thereby compensating for source fluctuations, photocell sensitivity, and other variables. Total measurement error is claimed to be within one-half percent. The light source is a chopped tungsten lamp with a six month lifetime. The photodetector is a vacuum tube multiplier. An Eltro transmissometer was tested for a short period of time at the National Oceanographic Administrations' Test and Evaluation Division facility in Sterling, Virginia. Results were generally favorable except for a problem with a short lamp life and inconsistent switching relays. No information has been provided regarding operating costs. It is all solid state with the exception of the lamp and

detector. Heaters are provided to prevent condensation. All components are on replaceable printed circuit boards. Aluminum and stainless steel are used throughout. Installation costs involve the costs of two concrete pads and the usual transmissometer cabling. The measurement range is 164 to 19,686 feet (50 m to 6,000 m) in the visual range (RVR). It is designed to operate over a temperature range of -30° F (-35° C) to 131° F (55° C). Power requirements are 300 w at 220 vac 50 Hz or 115 vac at 60 Hz.

j. IMPULSPHYSIK GMBH

1. The Fumosens

Impulsphysik has developed a large number of meteorological instruments including three instruments intended for detecting and measuring fog. The Fumosens was developed as an inexpensive fog detector for highway applications. It is a forward scatter meter much like the EG&G FSM but smaller and lighter, with a length of 3.3 feet (1 m) along the longest dimension, weighing 30 lbs (13.6 kg). It uses white light from a xenon flash lamp which is scattered to a photodiode detector at angles of 20 degrees or more. The electronics are all solid state. The operating range is 98.4 to 9840 feet (30 m to 3,000 m) in the visual range, and three adjustable alarm relays are available. It has a built-in direct indicator and can be used to drive a recorder located several miles away. It is intended to operate over a temperature range of -22° F (-30° C) to 113° F (45° C) in all weather conditions. Built-in heaters protect the optics and electronics, consuming 50 w at 110 v. A 12 volt model is also available. Day/night calibration is available. This instrument has evolved over five years and is currently in its third modification (Fumosens III) involving an extended measurement range and a more efficient package with increased protection of the optics from traffic dirt. The manufacturer claims it will operate for many months without requiring cleaning. No test data are available. Many of the older models (I and II) are deployed on various highways for evaluation, in addition to a model II under evaluation by the Air Force. The current price is $5,100 cif[1] (for delivery within the US) including one alarm relay and built-in direct indicator. Installation costs are low and operating costs involve replacement of the flash lamp ($450) every two to three years. Aging is automatically compensated.

A Fumosens I and II were evaluated by the Florida Department of Transportation during the fog seasons in the winters of 1973-74, 1974-75 and 1975-76, along with five other visibility sensors. No formal report was published as a result of the tests, and no decision was made concerning a selection of an instrument for Florida's fog problem. The primary reason was cost and the inability to pinpoint the fog area.

2. The Skopograph

The Skopograph is a long baseline transmissometer intended primarily for airport application and has been used successfully in highway applications. It is deployed extensively throughout Europe, Africa, and South America, but has found limited acceptance in the US because of difficulties in marketing foreign products for aviation use. It employs pulsed xenon light and will operate over baselines from 246 to 1476 feet (75 m to 450 m). At the shorter baseline the measurement range is 164 to 4,921 feet (50 m to 1,500 m) in the visual range. The electronics are all solid

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[1]Cost insurance and freight

state with exception of a vacuum phototube. Later models are being provided with photodiode detectors. The projector weighs 175 lbs. (79.4 kg) and requires 140 w, including heaters. The receiver weighs 114.4 lbs (52 kg) and requires 300 w. As with all long baseline transmissometers, substantial concrete bases must be provided for both transmitter and receiver and the alignment is critical. The Skopograph has built-in alignment capability minimizing the effort of this task, and calibration has been simplified with neutral density filters which simulate various visual conditions. The current price is $26,000 cif (delivered within the US duty-free), including recorder. Maintenance costs involve routine cleaning of optical windows and lamp replacement ($550) every 20,000 hours. No test reports are available; however, the Skopograph has been in routine use at many commercial airports since 1956.

3. The Videograph

The Videograph backscatter fog detector and visibility meter was developed in 1960 and today is deployed at more than 700 locations throughout the world. The US Coast Guard and Canada use it extensively for control of automatic fog warning systems for marine use. The projector and receiver are housed in one weatherproof housing weighing 106 lbs (48.1 kg). It samples the atmosphere from six feet (1.8 m) to 100 feet (30.5 m) ahead and measures over a range of 0.1 mile (0.16 km) to ten miles (16.1 km) in the visual range (lower and higher ranges are available on request). It has a built-in direct indicator and can be supplied with alarm relays for up to eight levels of visibility. It can also drive a recorder at a remote location. A built-in alarm delay is adjustable from zero to eight minutes to smooth out rapidly changing visibility conditions. Power consumption is 6 w with 28 w for heating. Special high output heaters are provided as an option for arctic conditions; however, the standard version will operate over a temperature range of -22° F (-30° C) to 113° F (45° C). It has a built-in failsafe device and manual circuit checks via a panel meter. The light source is a xenon flash lamp and there are no moving parts. The electronics are all solid state modular and it uses a photodiode detector. The unit is mounted on a pedestal ready for bolting to a small pad. The current price is $13,000 cif, including one alarm relay. A calibrator is available at $2,000; however, for highway applications, calibration can be accomplished by visual estimate during moderate visibility conditions. Operating costs involve routine cleaning of the optical windows and lamp replacement every two to three years ($550). The Videograph has been tested by the US Coast Guard, National Weather Service, and Canada, as well as the Oregon DOT and other state agencies. The unit is one of the most extensively tested devices of its type. The operation of the instrument has generally been satisfactory. In quantities, the Videograph is manufactured in the US, as are all Impulsphysik products; small numbers are more economically imported, according to the manufacturer. An MTBF of 35 years is claimed.

k. HAMAMATSU CORPORATION

Hamamatsu is a manufacturer of photosensitive devices, mainly closed circuit TV. A Company representative claimed existence of an ultraviolet transmissometer for highway application. Technical data and pricing information are not available as yet.

1. INTERNATIONAL LASER SYSTEMS, INC.

The Visibility Sensor Model VS-1 is a laser diode transmissometer operating on a 250 foot (76.2 m) baseline. This transmissometer was designed primarily for highway application. The transmitter and receiver are housed in separate environmentally-protected housings similar to highway posts. Heaters protect the optical windows from condensation. Alignment is accomplished using a built-in signal strength meter. The laser diode output is 20 to 30 watts in a one degree beam (no information is provided regarding new government laser safety standards). It is a pulsed semiconductor laser operating at 1 kHz. Four fog-level relays are incorporated in addition to an output for a recorder. The manufacturer claims that the long baseline of 250 feet (76.2 m) smooths out local fluctuations of visibility due to inhomogeneities in fog. However, such a configuration introduces more installation complexity and danger of disturbed calibration due to traffic vibration and other disturbances affecting the equipment. In theory, transmission measurements provide the most accurate visibility information, but the need for such accuracy in highway applications is unclear. The operating range in terms of visibility levels is from less than 100 feet (30.5 m) to greater than 1,000 feet (304.8 m) in the visual range. The device requires 55 w at 110 or 220 volts. The operating range is -40° F to 140° F, (-40° C to 60° C) and each unit weighs 35 lbs. (15.9 kg). Both transmitter and receiver mount on three inch (7.62 cm) schedule 80 pipe. The price is $6,750 in quantities of one to four and $4,250 for 20 or more. The manufacturer claims operating costs to be minimal due to all solid state construction. Installation is provided for $250 plus air fare. Prices are fob Orlando. On the basis of a fourteen month test of five visibility detectors, including the ILS instrument, followed by a utility-cost analysis of each, the Turnpike Authority selected the International Loser System Model VS-1, with the intention of installing five or six instruments in strategic locations where fog is known to be frequent.

m. LEAR SIEGLER, INC., ENVIRONMENTAL TECHNOLOGY DIVISION

Lear Siegler markets a number of transmissometers for environmental use. The SM4(VM4) is specifically designed for roadway visibility monitoring. It is a folded path instrument with a tungsten light source and receiver electronics located in one housing and a passive retro-reflector in a second housing. Typical instrument costs may vary from $15K to $20K per site, depending on the accessories required and the availability of stocks in the US. In addition to the SM4(VM4), Lear Siegler has several other transmissometer systems adaptable for visibility monitoring although they are intended for other uses, such as a smoke opacity measurement (e.g., the RM41). In most respects the RM41 is similar to the SM4. The output is calibrated in optical density and opacity. It uses an air purging system to keep the optics clean. No environmental suitability information other than stack use is provided. Considerable modifications may be required for highway application. The basic transmissometer is priced at $4,695 fob; remote readout unit with calibration controls, fault indicators, and dual alarm at $2,195; and air flushing equipment and protective housing at $1,995. For transceiver-reflector separations greater than 26 feet (7.92 m), a glass reflector option at $595 is required. All prices are fob. No test data are available. Operating costs are not available.

n. MARCONI RADAR SYSTEMS

1. The SM-5 Transmissometer

The SM5 transmissometer is manufactured in Germany and used by Marconi in its IVR-1 RVR system. A model SM4 is also reportedly available exclusively for highway use, but no information is presently available. As of 1975 the price of the SM5 was $12,646 fob Santa Monica and was marketed by LSI Astrionics, a division of Lear Siegler. According to recent contact with LSI, they no longer market this instrument. The price includes $9,195 for the basic transmissometer; $1,850 for a four point alarm, indicators and controls; $1,935 for protective housings; and $250 for the calibration kit. The SM5 is a folded transmissometer on a 492.2 foot (150 m) baseline and employs a split beam for output monitoring. The reflector housing employs an air purge system for maintaining cleanliness. The lifetime of the lamp is reported to be 10,000 hours. The device can measure visibility from 131.2 feet (40 m) to 18,046 feet (5.5 km) depending on the baseline. Power consumption is 35 w, and it will operate in temperatures of -22° F (30° C) to 140° F (60° C). Controls and recorder can be located up to 1.55 miles (2.5 km) away. Each unit weighs 68.3 lbs. (31 kg). No operating costs are available.

2. The MET-1 Environmental Transmissometer

The MET-1 Environmental transmissometer is a recent development of Marconi. The price when purchased from LSI Astrionics is $10,000 fob Santa Monica. The production price scheduled for 1976 was $6,000, but the US distributor is unknown. The MET-1 operates on a folded baseline of 13.1 feet (4 m) and is supported by a single pedestal. It uses a modulated LED as light source and has self calibration capability. Alignment is carried out at the factory, and there is no information indicating how a damaged unit may be realigned in the field. It weighs 772 lbs. (35 kg) and is 2.33 feet (0.71 m) long. Power consumption is 20 w at 115/230 v. It is designed to operate over a temperature range of 14° F (-10° C) to 122° F (50° C) in relative humidities of zero to 100 percent. Wind protection must be provided through site location. The manufacturer claims that the self calibration feature obviates the need for frequent calibration and cleaning of optical windows. The output is digital.

o. MEISAL ELECTRIC COMPANY

The Fognal Fog Detector is a new backscatter instrument which may be separated and operated as a transmissometer if desired. As a backscatter instrument, it will operate over a range of 32.8 to 3,281 feet (10 m to 1 km) or 328 to 32,180 feet (100 m to 10 km). The manufacturer claims automatic compensation for dirty optics and ambient temperature. Although not specified, it uses an LED or laser light source. It has a built-in alarm relay and current output to drive a recorder. Power consumption is 100 w with heaters on at 12 v. It is designed to operate over a temperature range of 23° F (-5° C) to 104° F (140° C). Weight is 39.7 lbs. (18 kg) for the TZE-2 and 19.8 lbs. (9 kg) for the TZE-4. No price information or test data are available.

p. MRI, INC.

The Fog Visiometer model 1580 is an integrating nephelometer (after Brewer and Beuttel, 1949). It integrates the scattering function between the angles zero to 150 degrees. This device has been tested and used by the California DOT with generally good results. The entire instrument is mounted on a single pedestal for ease of installation, and all components are in weatherproof housings. The device consists of a diffused light source (pulsed xenon) directed into a space open to the atmosphere. A photomultiplier detector views at an angle orthogonal to the light and towards a "black box" background, thus reducing background light. Only light scattered at an angle of 90 degrees can be seen by the detector. The device measures visibility at distances from 25 feet (7.6 m) to 15 miles (24.1 km), but is normally calibrated at distances between 260 feet (79.2 m) and two miles (3.2 km). Claimed accuracy is within 15 percent of the scattering coefficient. The electronics are solid state and automatic flash lamp aging compensation is provided. All optical surfaces are flushed by filtered air to maintain cleanliness. A built-in calibrator can be remotely activated. The output is suitable for driving a recorder or direct indicator. Information on relays for handling currents necessary to activate warning indicators is not available. Power requirements are 50 w at 110 v. It weighs 43 lbs. (20.4 kg), and the price is $4,985 fob without output device. The manufacturer claims low maintenance costs, with flash lamp replacement at $15 per year. Spare cards are available at $1,500. No test data are available.

q. SCHLUMBERGER

The Helios transmissometer is used in the Helios-Caviar RVR system. No detailed technical or pricing data are available at this time.

r. SIAP

The SIAP TA 6006 is an airport type transmissometer which measures in the range of 328 feet (100 m) to 3281 feet (1000 m) in the visual range. The baseline is typically 164 feet (50 m). Transmission is measured by comparing the light output at the source to the light output at the detector. The source is a 100-watt incandescent lamp rated at 2,000 hours. Alignment is carried out via reflex viewing. The projector requires 200 w at 220 v, is all solid state (except the lamp), and weighs 233.2 lbs. (106 kg). The receiver uses a photomosaic detector and requires 150 w at 220 v, is all solid state, and weighs 238 lbs. (108 kg). Both housings are thermostatically controlled. The outstanding feature claimed by the manufacturer is that it is insensitive to power fluctuations and to individual intensities of the primary and reference lamps. No price information is available as yet.

s. SNECMA

The Lynx transmissometer is used in the TI 561 RVR system. Such a system is undergoing evaluation by the FAA. The transmissometer measures atmospheric transmission with 0.2 percent accuracy using 100 foot (30.5 m) and 130 foot (39.6 m) baselines, and 0.5 to one percent accuracy using 160 foot (48.8 m) and 250 foot (76.2 m) baselines. Both transmitter and receiver weigh 33 lbs. (15 kg). The system is designed to operate over temperatures from -22° F (-30° C) to 122° F (50° C). The 1975 price was $12,000 fob not including output device. No additional information is available as yet.

t. PHOTOBELL COMPANY INC.

The Photobell instrument Type 4784MF is a transmissometer. A pulsed LED signal is directed towards a 50 foot (15.2 m) distant retro-reflector and returned to the source. A prototype was installed on the New Jersey Turnpike, where it was evaluated with four other visibility detectors. (See item 1 above.) The prototype instruments cost is about $10K, but the manufacturer estimates cost at $2K if manufactured in quantity.

u. THE PLESSEY COMPANY, LTD.

The Point Visibility Meter (PVM) is an enclosed forward scatter meter that measures light scattered by a small atmospheric sample in a central opening oriented at a small angle to the path of the direct beam, and compares this to the direct beam. Enclosed construction protects it from road dirt. However, the small opening provided for the atmospheric sample is a natural collector of debris and insect webbing and thus must be cleaned on a monthly basis. The device uses a GaAs light source and a photodiode detector and is all solid state. It will measure over a range of visibilities from 164 to 16,400 feet (50 m to 5 km). Claimed accuracy is within 15 to 20 percent in the visual range. Power consumption is 10 w, and it operates on ac or dc power, depending on users option. The operating temperature range is 14° F (-10° C) to 122° F (50° C) from zero to 100 percent relative humidity. It weighs 13.4 lbs. (6.1 kg) and is 11 inches (280 mm) in diameter. A separate power unit weighs 9.0 lbs. (4.1 kg) and is 7.9 inches (200 mm) along the longest dimension. It will drive a recorder or an optional relay for alarm control. It is capable of remote display up to 16,400 feet (5 km) away. Calibration using the calibration unit is recommended on a monthly basis. The theory of operation is sound, and the unit has received wide attention in the United Kingdom. One was tested on the M4 highway with favorable results reported by the local highway authority. Another is now under evaluation on the M1 highway. No independent test reports are available at this time. The manufacturer states that the British and French Meteorological Offices have selected the PVM over US, German, and other United Kingdom devices, and interest has been shown by German and Dutch authorities. The current price is £3100 fob with the calibrator priced at £800. Customs duty is about 15 to 20 percent.

v. TASKER INDUSTRIES

The Tasker Model 500 transmissometer is an all solid state update of the transmissometer found on most US commercial airports. This FAA approved transmissometer has been developed over many years and is well proven in the field. The Model 500 still uses a filament type lamp. A projector modification holds the light output constant to within one percent. It will operate from -58° F (-50° C) to 158° F (70° C) at zero to 95 percent relative humidity. The receiver/pulse amplifier is now all solid state with a photodiode detector. The silicon diode has a diameter twice the size of the image to allow for alignment drift. The new detector is 200 times more sensitive. The MTBF is estimated to be 13 years. The power supply is now also all solid state. Power consumption has been considerably reduced. The price of the Model 500 is $25,000 fob including recorder.

w. WEATHER MEASURE CORPORATION

The WM74-F fog detector is a backscatter type instrument with automatic compensation for deteriorating light output due to dirt on lenses or other causes. It uses a GaAs LED pulsed at 1 kHz to reduce background noise. Automatic temperature compensation is also provided. All of this is accomplished, according to the manufacturer, by monitoring the light output from the projector lens. A life expectancy of 100,000 hours for the LED is claimed. The fog detector comes in either a 12 v or 110/220 v version. Recommended operation is on ac power with dc backup. A built-in preset alarm relay is provided with the option of a multi-point alarm control. It is available in both a 32.8 foot (10 m) to 3,280 foot (1 km) and a 328 foot (100 m) to 32,800 foot (10 km) visibility version. Heaters are built-in to prevent condensation on the optical windows. The unit will also drive a recorder or direct indicator. The device is compact and mounted on a single pedestal. The weight is 20.5 lbs. (9.3 kg). An accuracy of one percent is claimed. Power consumption is 100 w with heaters. The operating temperature range is 19° F (-10° C) to 104° F (40° C) (because of this, use as a snow detector is doubtful). The price of the low visibility range model is $4,500 fob, while the higher range model is $10,300 fob. The mounting pedestal is $95 extra. Operating costs have not been supplied. No test reports are available.

Weather Measure also supplies a transmissometer designated the WM73-T. This also uses an LED light source modulated at 1 kHz. It employs automatic feedback to control the light output providing a claimed accuracy of 0.8 percent. The baseline can be selected at 32.8 feet (10 m) to 820 feet (250 m). The receiver uses a silicon photodiode detector. Power consumption is 160 w. The projector and receiver each weigh 22 lbs (10 kg) and each mounting pedestal weighs 176 lbs. (80 kg). It is supplied in a 110/220 vac or 12 vdc version. It will drive a direct indicator, recorder, or multipoint alarm device. Price is $13,905 fob, recorder $1,416, pedestal $139 each, multipoint alarm $1,892, calibrator $385, field test kit $360, and output test kit $669, all fob. No operating costs are available. The manufacturer claims long life for all components, which are all solid state. No test reports are available.

x. MCGRAW EDISON COMPANY

The Edison Fog Responder Model 905872 is a forward scatter device whose transmitter and receiver are separated by a distance of 15 inches (0.38 m). Ultraviolet light emitted by a mercury vapor discharge lamp is focused by a parabolic mirror in the transmitter into a cone passing through the quartz window in the unit. An exterior baffle provides a dark space in the cone of light within which the receiver is placed. The receiver, therefore, cannot see any direct radiation from the transmitter. The receiver provides a continuous analog voltage which varies with changes in fog density, and which is measured by a voltmeter calibrated in the visual range between 50 feet (15 m) and 1,000 feet (305 m).

2-3 APPLICABILITY OF VISIBILITY DETECTION EQUIPMENT

a. FOG ENVIRONMENT

The transmissometer is inherently more accurate than other types of visibility measuring instruments. However, installation costs are generally higher as are typical purchase prices excepting a small number of special highway transmissometers. Transmissometers are generally more sensitive and vulnerable to alignment disturbances. The Colorado Optics 172B, International Lasers VS-1, and TRRL folded transmissometers are all of interest for highway application, especially the latter because of the single pedestal feature. The other two require an unobstructed path and are more vulnerable to disturbances caused by traffic vibrations, road maintenance functions, etc.

The forward scatter meter should be considered next in terms of measurement accuracy, if accuracy is a factor for highway applications (which is doubtful). In terms of price, the Fumosens and PVM are most attractive. The EG&G FSM has received the most testing and has a broader measurement range with greater accuracy. However, broad range and great accuracy are not necessarily required for highway fog detection which may not require better than 25 percent accuracy in the 1,000 foot (304.8 m) or less visibility region. The MRI side scatter should probably be considered in this group also (Visiometer).

Among the backscatter devices, the Videograph is the most fully developed and had received the most independent testing. However, it is more expensive than the forward scatter devices mentioned above. The Weather Measure WM74-F is in the forward scatter price range, but is not as well known.

The State of Florida conducted a series of tests over a three year period during the winters of 1973-74, 1974-75 and 1975-76. Seven reduced visibility sensors in all were evaluated; a converted Hewlett Packard instrument, the International Loser Systems VS-1, and Impulsphysik Videograph, the Fumosens I and Fumosens II, the MRI Visiometer and the EGG Model 209.

All instruments, with the exception of the Videograph, experienced problems with insects attracted to the light source. Generally, all the instruments gave fairly consistent readings, although the Videograph, designed for a marine environment, gave readings closest to the estimates obtained visually by observing distant markers.

The VS-1 was considered to have a problem in that condensation on the reflector and beam wandering, produced by component temperature stress during the diurnal cycle, caused false readings.

Most maintenance problems were minor; however, the visibility instruments were not considered to be as reliable as some other traffic equipment, e.g. signal controllers.

No formal report summarizing the tests was published. It had been intended to select one of the instruments as best suited to deal with Florida's fog problems, but it

was decided that it would not be an effective solution because the visibility sensors were expensive and because the location of the fog area could not be considered fixed in time or geography.

The New Jersey Turnpike conducted a fourteen month test spanning three fog seasons in which five instruments were tested; the International Laser System VS-1, the Edison Fog Detector Model 905872, the Visiometer Model 1580A manufactured by MRI, the Photobell Type 4764 MF transmissometer, and the Videograph Model B, manufactured by FF Impulsphysics.

The purpose of the program was to determine which visibility detector or detectors most accurately defined visibility levels as seen with the human eye; which were most sensitive to visibility level changes; which were installed most easily; and which required the least maintenance.

Extensive testing and comparison was done, and a utility-cost evaluation was carried out to make the final selection of an instrument type which would meet the New Jersey Turnpike needs.

The New Jersey Turnpike selection was the International Laser System transmissometer Model VS-1, which will be used to monitor five or six strategic locations on the Turnpike. The selection was strongly influenced by VS-1 dependability, baseline length, responsiveness and cost.

b. BLOWING SNOW, SAND, AND DUST ENVIRONMENTS

The manufacturers and distributors of visibility detection equipment were surveyed via telephone contact to identify the present users and/or applicability of the equipment in a reduced visibility environment resulting from blowing snow, sand, and dust. The following paragraphs provide a summary of the survey results.

1. FF Impulsphysics Corporation

Impulsphysics manufactures three types of visibility sensors suitable for highway application: the Fumosens (forward scatter type), the Skopograph (transmissometer type), and the Videograph (backscatter type). All three visibility detectors were developed with the intention of detecting and measuring fog. However, representatives of Impulsphysics indicated that any one of their three sensors have the capability to provide visibility measurements during blowing snow, sand, and dust conditions. The Skopograph unit was cited as being more applicable and accurate than the other sensor types when applied in a snow, sand, or dust condition. The Skopograph, which is a baseline transmissometer that measures the attenuation of light caused by particle absorption and scattering, can be applied in the three reduced visibility environments under consideration. There has been no formal testing conducted by the manufacturer on the Skopograph detector under either a blowing snow, sand, or dust condition. However, some units are presently being used by a highway agency in South Africa to activate motorist dust warning signs.

Domestically, one unit is presently being used on Interstate 10 near Thousand Palms, California to operate a sign warning motorists of blowing sand conditions. The sign site is frequently prone to wind storms that will cause neighboring sand to become airborne whenever the desert floor is dry. The resulting sand storms in the area restrict motorist visibility and cause abrasion damage to vehicles. Westbound vehicles on Interstate 10 often enter sand storms head-on, creating severe abrasion damage problems. A Caltrans study of the area concluded that abrasion damage to westbound vehicles could be minimized if vehicle speeds are no higher than 15 mph. The warning sign used is internally illuminated and displays the message, BLOWING SAND - SLOW 15 MPH. Flashing lights mounted alongside the sign are used to attract motorist attention. The sign is located one-third mile upstream from the Skopograph unit and is oriented towards the westbound traffic lanes. The unit is directly connected to the warning sign so that when visibility drops below a predetermined threshold, a signal is sent to the sign to display the warning message and power the flashing lights. Caltrans has not formerly evaluated the effectiveness of either the sign or the Skopograph; however, the warning system has been effective.

2. International Laser Systems, Inc.

The Model VS-1 Visibility Sensor is a baseline visibility sensing device (a transmissometer) designed primarily for highway application. The manufacturer claims the VS-1 can also be used to detect and measure snow, sand, and dust conditions. This claim is based on the instrument's principle of operation (transmission) to provide accurate visibility information. However, no test data are available on the instrument performance in other than a fog environment. The VS-1 has been tested by the New Jersey Turnpike Authority but only under fog conditions.

3. Meteorology Research, Inc. (MRI)

The Fog Visiometer is a total scatter device which measures vision obscuring effects of light scattering from water droplets or solid particles in the air. The manufacturer claims the instrument can also be used to detect high concentration dust in the air; however, no test data are available.

4. EG&G, Environmental Equipment Division

The Model 207 Forward Scatter Meter was developed by the manufacturer under a research contract with the US Air Force. The instrument has been extensively tested by the Air Force Cambridge Research Laboratory (AFCRL) under a variety of weather conditions. The AFCRL collected some performance data under a snow condition; however, no formal or internal report interpreting the results has been written. An AFCRL representative directly involved with the testing indicated that the instrument's operational performance in a snow condition was good. An adjustment in the heater elements (located on the glass optics) was necessary during the testing to ensure proper instrument performance.

5. Other Manufacturers

The following manufacturers indicated their visibility detection equipments have not been applied in any of the environmental conditions under consideration (snow, sand, and dust), but stated their equipment could operate under such environmental conditions. No data or material were forthcoming to confirm this claim, however.

- Lear Siegler, Inc. - SM4 Transmissometer
- Tasker Industries - Type FA-8998 Transmissometer Set
- Photobell Co., Inc. - Fog Transmissometer
- AGAtronics Ltd. - Model FDNA Fog Detector
- McGraw Edison Co. - Edison Fog Detector.

In summary, study of the difference between fog and other visibility impediments such as sand or smoke, in terms of particle size, reflectability, and shape, favors the use of a transmissometer-type instrument, especially in the case of blowing sand. As far as is known, this conclusion is the result of practical experience; no theoretical analyses have been found to date.

On the other hand, detection of snow particles has been the subject of extensive research and development by the Wyoming State Highway Department. An effective instrument has been developed and is in use in several locations on an 80 mile (128 km) stretch of Interstate I-80 near Cheyenne Wyoming. The snow detector is not commercially manufactured.

Section 3

CLOSED CIRCUIT TELEVISION (CCTV) SURVEILLANCE EQUIPMENT

3-1 INTRODUCTION

The use of CCTV for visually observing visibility conditions has been investigated by the Federal Aviation Administration (FAA).* The FAA concluded that good or poor visibility conditions could be adequately determined, but evaluation of marginal conditions depended on picture quality and the type of background terrain being viewed. The FAA report indicates standard off-the-shelf TV cameras are suitable and should have standard resolution with good grey scale retention over a wide dynamic range.

The FAA report recommends use of the silicon matrix tube because of sensitivity and resistance to burning from direct solar rays. Automatic light compensation is required as the camera should operate over a dynamic range of 100,000 to 1. The best lens for this application is reported to be 0.98 inch (25 mm) or 1.96 inch (50 mm) focal length for the best combination of viewing and field of view. A slow scan transmission system is recommended for ease of picture transmission from remote locations (refer to paragraph 3-2).

A recent privately-funded study by Stanford Research Institute (SRI) (Feasibility of a Vidicon Camera Visibility Monitor; W. Viezee, SRI 1975) indicates the feasibility of using CCTV for actually measuring visibility. The technique, which is proprietary, utilizes direct measurement of the contrast ratio (the fundamental basis for determining visibility) between an object at a known distance and its background. The technique is feasible because of the linear response of silicon target tubes which have a stable and highly linear brightness transfer characteristic. Experiments were conducted using a CCTV camera marketed by COHU Electronics which used the RCA 4532 vidicon tube with a silicon diode target array structure. The system employed standard resolution of 525 lines. The camera used a 10-to-1 zoom lens to isolate objects under evaluation.

Pan and tilt controls and diaphragm control are required. Recent technological breakthroughs in microprocessor techniques and camera design have encouraged SRI to undertake a prototype design which it had expected to demonstrate in the spring of 1978.

No information concerning the Videometer CCTV visibility measuring device mentioned in Section 2, Visibility Detectors, had been received from the manufacturer as of the date of this report.

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*Remote Monitoring of Visibility in Mountain Passes, Joseph Czika, Kenneth H. Schreeve, Rep. No. FAA-RD-74-53

3-2 CCTV SURVEILLANCE EQUIPMENT MANUFACTURERS

Appendix B summarizes the result of the survey of equipment suitable for CCTV tasks. A summary of pertinent information by manufacturer in alphabetical order follows (Appendix H lists manufacturer addresses). Caution in using cost data is advisable because estimates of typical costs vary widely, depending on location and communications, among other factors.

a. COHU, INC.

Cohu has a broad background in CCTV applications for outdoor surveillance systems. They manufacture a line of self-contained environmental TV cameras ranging in price from $2,000 to $11,900. The range of specifications is too broad to list in this report. Cameras are available with silicon target, Newvicon, or standard vidicon tubes. All cameras are designed to operate in adverse environments in temperatures down to -40° F (-40° C). They are intended for automatic unattended operation with remote control capability and are tamperproof with no exposed controls. They are constructed from all solid state electronics with etched glass epoxy circuit boards and FET inputs. Appendix B indicates a recommended camera-tube combination. A typical MBTF is 16,800 hours with typical annual maintenance of 0.5 man-day.

b. GENERAL ELECTRIC

GE has a low cost environmental CCTV camera suitable for use with silicon tubes (Epicon, GE silicon target tube). Camera and tube cost about $650. A fixed focal length lens with automatic iris (required with a silicon target tube) costs about $200. GE does not list a zoom lens. The light level range of the camera with silicon tube is 100,000:1. A low noise FET preamp is used. Input power requirements are 12 w at 117 v. It is designed to operate over a temperature range of -22° F (-30° C) to 140° F (60° C) at 100 percent relative humidity up to 15,000 foot (4572 m) altitudes. No information is given regarding automatic operation or remote control. Tube replacement is required every two years for $350.

c. HAMAMATSU TV COMPANY

This Japanese company specializes in relatively expensive CCTV systems with precision controls for remote measurement and observation systems for science and medicine. Their C1000 camera series is priced from $3,500 to $12,500, including controls. They do not have a special environmental camera for use in an outdoor unattended situation.

d. MOTOROLA

Motorola markets a complete line of CCTV surveillance equipment, including control centers. The broad line of camera specifications is too extensive for this report. The camera equipment includes high performance vidicon cameras, and low light level cameras with silicon intensified vidicons or single intensified heterojunction vidicons. They market from remote-controlled pan and tilt equipment to complete digital control systems. The recommended camera for indoor/outdoor

operation uses a diode array vidicon (silicon hetero-junction), and costs $7200 with lens and servo-controlled neutral density filter for light control. This tube is infrared (IR) sensitive and would need a filter to exclude IR for visibility surveillance. The tube is resistant to burn by light sources and is automatically protected from burning caused by beam scan failure.

e. RCA

RCA also supplies a broad range of CCTV cameras varying in price from $290 for a standard vidicon camera with fixed focal length, to $4035 for a low light level camera with remote-controlled zoom lens. Outdoor housings are available at extra cost. Appendix B summarizes the RCA recommendations. Operating costs vary according to the type of tube selected, as reflected by replacement costs. Remote-controlled pan and tile units are available also, as well as the remote control units themselves.

f. SONY CORPORATION OF AMERICA

A low cost vidicon surveillance camera, including lens, is available from Sony for $375, without an environmental housing. A surveillance camera with an optional automatic iris lens is also available at $13.00. (See appendix B.)

g. LAKE SYSTEMS

This TV systems company specializes in outdoor surveillance systems. Installation costs of CCTV surveillance systems are strongly dependent on the specific system and very difficult to generalize. The entries in Appendix B are typical costs for equipment suitable for highway surveillance, according to Lake Systems experience. The camera costs include zoom, pan, and tilt with appropriate controls.

3-3 SLOW SCAN CCTV

The FAA report on visibility surveillance in mountain passes (refer to paragraph 3-1) mentioned use of slow scan TV equipment making possible transmission over long distances using standard telephone lines. Two systems were mentioned: one manufactured by RCA and one by Colorado Video Inc., of Boulder. RCA no longer manufactures its system, but Colorado Video Incorporated (CVI) system is still available. In addition to normally-required CCTV cameras, controls, and monitors, a special transmitter and receiver are required.

The transmitter (Model 260) takes the picture from a standard TV camera at a rate of 60 pictures per second, and transmits it via telephone line at one picture per minute. The receiver at the other end reconstructs the picture for a standard monitor. The transmitter costs $3,000 (a low cost $1,500 version is under development), and the receiver costs $9,000 for 240 by 256 picture elements and $12,000 for 240 by 512 picture elements.

3-4 TYPICAL CCTV SYSTEM COSTS

System costs vary by an order of magnitude, depending on camera, controls, communication and central facility requirements. A detailed tradeoff of alternatives is necessary to arrive at good estimates. However, a rough idea of costs can be obtained from the following example.

Assume a ten-mile (16.1 km) long stretch of highway to be equipped with a controllable camera every two miles (3.2 km), using a coaxial cable link. Typical system costs are as follows: $5,500 to $11,000 per camera location, according to tube type; $5,000 per mile ($3,100 per kilometer) for coaxial cable link; $100,000 for control console with monitors and status board; $3,500 per location for modulator/demodulator; and $600 per position for digital control equipment. Thus, a five camera system covering ten miles (16.1 km) of highway could cost between $200,000 and $230,000, exclusive of terminal boxes, mounting poles, conduit, and installation costs.

Section 4

VEHICLE DETECTORS

4-1 INTRODUCTION

Vehicle sensors (detectors) may be used to enhance the overall performance of RVG systems. Of the several types of sensors available, inductance loops and magnetometers best fulfill vehicle surveillance requirements for RVG systems. This section will examine major lines of loop and magnetic sensors on the market and discuss criteria to be considered in choosing a unit for an RVG system. First, the potential objectives of vehicle sensors are discussed.

4-2 USE OF VEHICLE SENSORS

Vehicle sensors find use in RVG systems by providing the following information:

- Traffic volume
- Lane occupancy
- Traffic speed
- Vehicle classification.

a. VOLUME

Volume is obtained by a timed summation of individual pulses output by the sensor. In a real-time surveillance system, volume is used primarily for the measurement of demand. Control center personnel, who are aware of a reduced visibility condition, need to know the demand volume on the road to estimate the hazard. In certain instances of high volume and low visibility, a controller would be able to place on standby, or even deploy, emergency highway personnel, before receiving reports of any incidents.

Volume sensors, if located both upstream and downstream of probable congestion sites, can be used to detect the occurrence of incidents. A downstream volume count significantly lower than the upstream volume count may indicate an incident; the reverse condition indicates clearing of the congested condition is in progress. Although this incident detection technique requires fewer sensors, it does not match the accuracy of a speed or occupancy-based technique.

In sophisticated systems, volume data are therefore used primarily for measurement of demand. If recording capability is provided, volume data can also be accumulated for prediction and planning purposes.

b. OCCUPANCY

The occupancy parameter, a measure of vehicle density, is most important for determining the occurrence of capacity-reducing incidents on the roadway; that is, when the demand exceeds the capacity of the restriction, congestion develops and increased occupancy is observed at detector stations upstream from the incident. To provide rapid response incident detection using vehicle sensors, two basic requirements must be met. First, fairly extensive detectorization (at least one sensor site every half-mile (0.80 km)) is needed; second, with present incident detection techniques, reasonably high volume (approximately 1,000 vehicles/hour/lane) must be present. However, the vehicle sensor complement can be strategically located within primary hazard zones of the system, and limited, locally-oriented incident detection capability can also be provided. This function would then be based primarily on speed data, as described below.

c. SPEED

Speed data have direct relevance to the RVG system. Specifically, speed might be used to verify the occurrence and sensitivity of reduced visibility hazards; to fill in for missed or late detections at individual visibility sensors; and to determine an advisory speed to be displayed during the hazard condition. In general, the speed limit at which a sign is set during the reduced visibility condition should be a function of the measured speeds of vehicles within the hazard zone, unless this speed is substantially above a safe operating speed based on visibility considerations.

A secondary function can be provided by speed data, namely, a limited incident detection capability. If visibility sensors are located within primary accident zones of the system, the measured speeds can provide an indication of a partial or complete roadway blockage immediately downstream of the vehicle sensor site.

d. CLASSIFICATION

Classification data can serve a secondary function in RVG systems on highways which normally experience high truck volumes. In view of potential differences in speeds between these vehicles and cars, particularly on upgrades and downgrades, the calculation of speed by vehicle category may provide useful information. Two separately-defined speed thresholds in the detection logic, one for cars and one for trucks, may thus be necessary.

e. POTENTIAL ADDITIONAL USES OF SENSOR DATA

Various sensor configurations also provide the following types of data:

- Total volume
- Auto volume
- Bus/truck volume
- Average auto speeds
- Average bus/truck speeds.

These data can be provided on a continuous daily basis, for any averaging period desired. Also, two-detector traps can be used to detect "wrong-way" vehicles.

f. SENSOR CONFIGURATION

Different types of systems warrant different sensor configurations. For example, a short section of road occasionally immersed in steam or smoke from an adjacent factory may use a speed detecting sensor in conjunction with a visibility detector. By locating both detectors near the center of the visibility danger zone, approaching motorists will be advised to maintain a specified safe speed. Volume, occupancy, and classification data are not particularly useful to a small and simple system.

Alternatively, a major freeway subject to patchy, low-lands-type fog would be expensive to fully implement with speed detectors. A system of locating sensors at reasonable intervals along the highway must be developed. Data from the sensors can be collected and interpreted at a control center by computing equipment and qualified personnel. The sensors would be most valuable if they provide several types of data to the operators, such as volume, speed, and occupancy.

Still other visibility systems may not significantly benefit from the use of vehicle sensors.

Those systems which usually benefit the most are systems combining other functions into a total control system. Often other functions included are road surface, accident, congestion, and diversion advisories.

Because traffic operations are not typical during a reduced visibility condition, using detectors on one lane of a multi-lane roadway may not be sufficient. For this reason, detectorizing all lanes may be necessary. Figure 1 shows a typical two-lane speed trap configuration using inductive loop detectors. Figure 2 shows a similar configuration using magnetometers.

4-3 TYPES OF VEHICLE SENSORS

Inductive loop detectors are the most commonly used in RVG systems. However, sonic and magnetometer detectors also have the capability of providing volume, occupancy, speed, and classification data. Magnetic detectors, which differ from magnetometers by their inability to measure vehicle presence, are of less use to RVG systems. Other sensor types, such as microwave and optical sensors, are considered to be poor candidates for this application because of their performance, cost, or availability.

Sonic detector heads can normally be either mounted overhead or side mounted. However, overhead mounting is necessary to provide classification data because of the above-height measurement restriction. This restriction requires the use of some existing structure (i.e., sign bridge or overpass) on which to mount the detector. The alternative is to provide an expensive new structure, either overhead or cantilevered. The cost of such a structure for sensor installation is substantially more

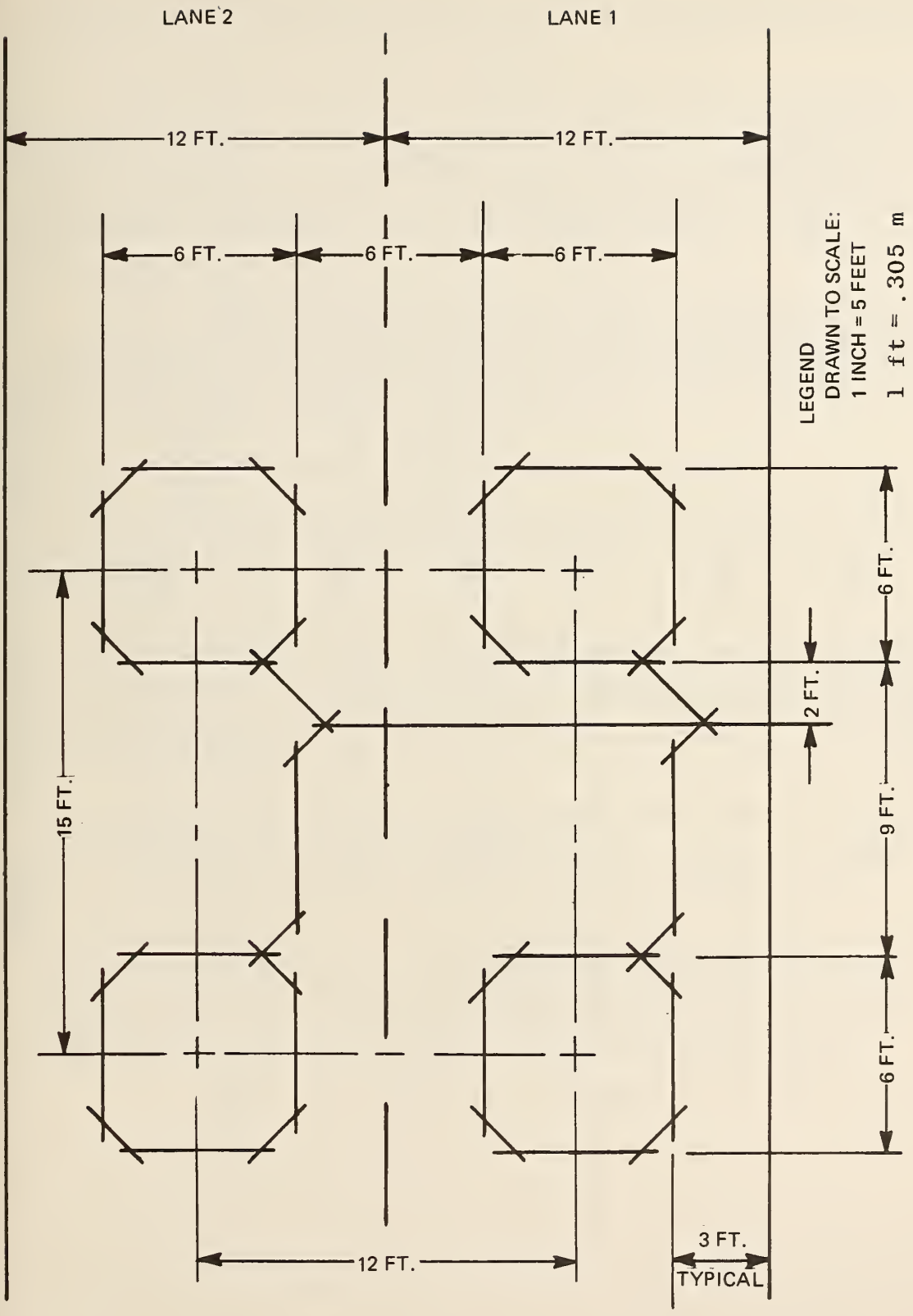


Figure 1. Typical Loop Detector Configuration

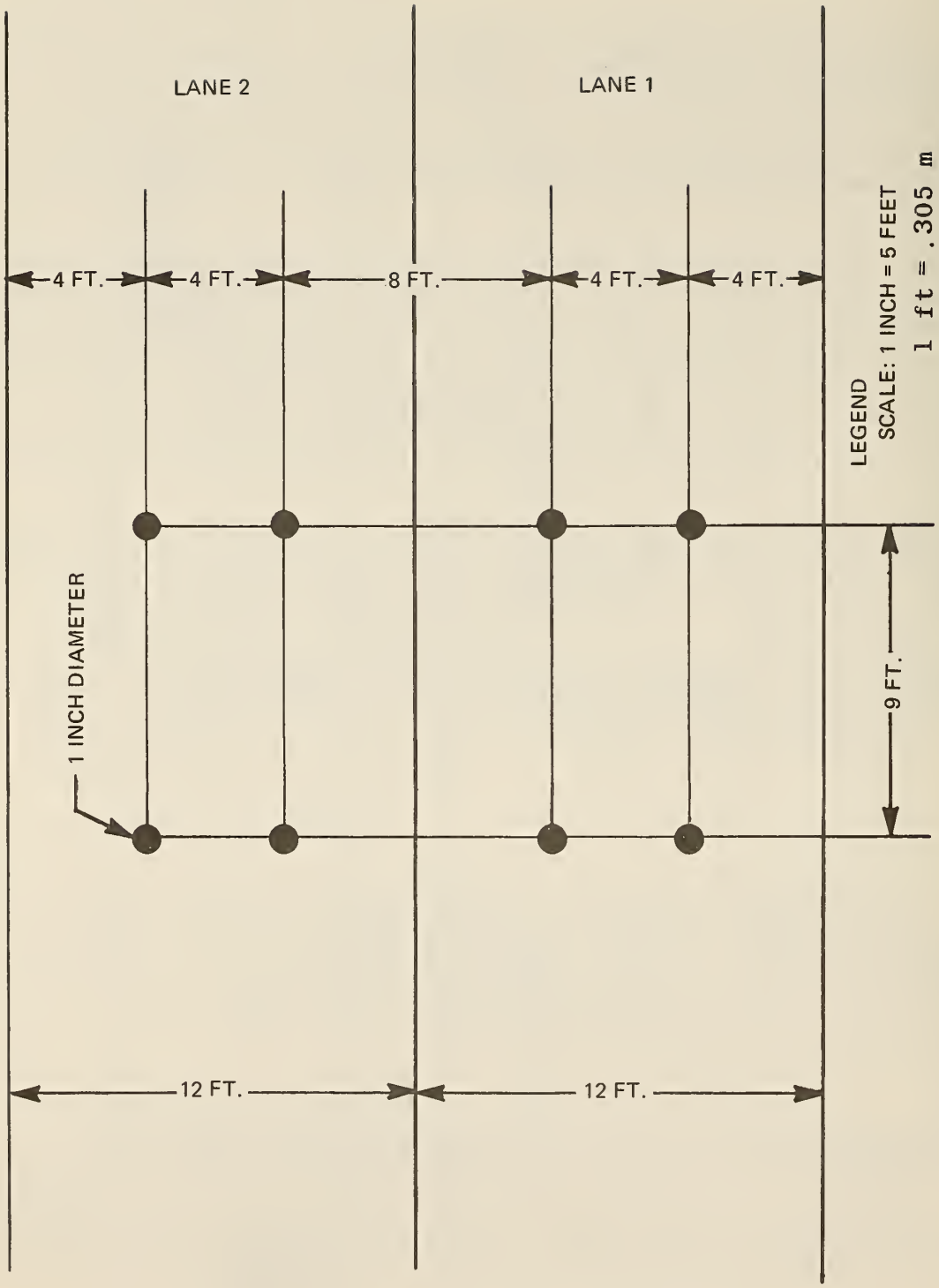


Figure 2. Typical Magnetometer Configuration

than the total installation cost of either inductive loops or magnetometers. Thus, for RVG systems requiring large numbers of vehicle sensor sites, sonic detectors are not considered viable detector candidates.

Relative advantages and disadvantages of magnetometers and inductive loop detectors are compared in Table 1. Either detector type can provide the necessary data with adequate accuracy and reliability. Generally, magnetometers offer a lower installation cost, slightly greater reliability, and longer permissible lead-in length. Inductive loop detectors offer improved accuracy in measuring some parameters, and a lower drop-out rate for high-bed trucks. However, none of these advantages are significant.

The one significant advantage of loops is their widespread use among highway organizations. This has resulted in a wider variety of loop amplifiers on the market. For this reason, loops are first choice for use in most RVG systems. Magnetometers should be used when lead-ins are over 1,000 feet (304.8 m), or when pavement is prone to frequent cracking or frost-heaves.

4-4 DETECTOR AMPLIFIERS CURRENTLY AVAILABLE

Approximately ten companies manufacture the vast majority of detector electronics in the US. Table 2 lists these companies and the types of detectors they manufacture.

Several other companies, whose names are prominent in traffic engineering circles, have recently stopped manufacturing their own models in favor of marketing more competitive units. These units are manufactured by the ten companies under seller's nameplates. This report examines only those units carrying original manufacturer's names. Specifications for other units are generally identical to those described herein.

Appendix C lists manufacturer advertised specifications for inductive loop, magnetic, and magnetometer electronics units.

4-5 CONSIDERATIONS IN CHOOSING DETECTOR AMPLIFIERS

Several manufacturers carry well-rounded lines of loop detector amplifiers, while others specialize in only a couple of models (refer to Appendix C). Some units currently on the market are designed for specific purposes while others are meant for general use. Criteria to be used in choosing between the various manufacturers and models are considered in the following paragraphs.

TABLE 1. VEHICLE SENSOR TRADEOFFS

Characteristic	Magnetometer	Inductive Loop Detector
Roadway installation cost for two detector traps in each of two lanes.	$700	$1,700
Remaining installation cost	*	*
Detector electronics cost	*	*
Communication costs	*	*
Central Data Processing requirements	*	*
Reliability and Maintenance		
Electronics	* (average 5-10 year MTBFs)	*
Roadway Installation	Better than inductive loops because of smaller surface installation area	More prone to be affected by break-up of pavement because of installation area; particularly a problem in areas of frequent freeze-thaw cycles.
Pickup and Dropout Characteristics		
Repeatability of detector pickup characteristics		Acceptable for accuracies required; five percent error in speed is allowable
Pickup shadow compared to actual vehicle shadow	Acceptable for accuracies required for classification	6 by 6 foot (1.8 m by 1.8 m) loop better than magnetometer
Dropout for high-bed trucks	Eight to ten percent of tractor-trailer or other high-bed trucks with relatively low metallic content; however, this condition can be corrected by either hardware or software, if desired	Less likely to drop out for tractor-trailer or high-bed trucks
Performance for high speed vehicles	*	*
Performance for low speed vehicles	*	*

*Indicates equivalent characteristics for both types of sensors

Table 1. Vehicle Sensor Tradeoffs (Continued)

Characteristic	Magnetometer	Inductive Loop Detector
Environmental Operation Temperature Humidity Snow or ice on pavement Local high voltage line	*	* Less prone to electrical effects
Maximum lead-in length without affecting accuracy	5,000 feet (1.5 km)	1,000 feet (0.3 km); this length is acceptable for most proposed field equipment layouts
Effects of subsequently paving over roadway detector installation	Heat or depth of probe no problem; in fact, the performance actually improves with greater probe depth, although sensitivity decreases	Performance not affected by heat or depth of loop
Number in use	Fewer than loops, but nevertheless large and increasing in number	Extensive
Relative availability of associated software algorithms	Some development	Extensive development

*Indicates equivalent characteristics for both types of sensors

TABLE 2. SUMMARY OF VEHICLE DETECTORS ON THE MARKET

Company	Analog Loop Detector	Digital Loop Detector	Magnetic Detector	Magnetometer
Automatic Signal, East Norwalk, Connecticut			1*	
Canoga Controls, Canoga Park, California		2, 4		1, 2
Decatur Electronics, Decatur, Illinois	1		1	
Eagle Signal, Austin, Texas	1	**	1	
Enerco, Seattle, Washington		8, 16		
Fosco, Dixon, Illinois		**		
Gammatronix, Dublin, Ohio				1
Indicator Controls, Gardena, California		1, 4		
Sarasota Eng., Sarasota, Florida	1			
Streeter-Amet, Grayslake, Illinois	1, 2			
Traffic Data Systems, Colorado Springs, Colorado	1			

*Digits refer to number of channels per unit
**Unit to be marketed soon

a. COST

The costs shown in Appendix C are prices for one unit purchased directly off-the-shelf. For quantity orders, manufacturers offer sizable discounts. Examples are as follows:

- Manufacturer A: 20 units, 45 percent off
- Manufacturer B: 100 units, 40 percent off
- Manufacturer C: 2-10 units, 10 percent off; 11-50 units, 20 percent off; more than 50 units, negotiable.

Because marketing is limited, large quantity prices are frequently negotiated. If an order is up for bid, prices will generally fall below listed discounts.

Most manufacturers are willing to modify specifications to meet special requirements for quantity orders. Therefore, a manufacturer who does not advertise the sale of a certain type of unit may still be qualified to fill bulk orders of the unit.

Costs of multichannel units are naturally greater than those of single channel units. However, multichannel-unit cost per channel is generally less, and its use proves to be cost effective at multi-sensor sites.

Although the detector electronics unit comprises only a fraction of the total sensor installation cost, the remaining expenses are, with a couple of exceptions, not dependent upon the choice of models. Those exceptions are as follows: If a plug-in board-mounted unit is purchased, an additional expense is incurred to purchase and install a standard five inch (12.7 cm) card rack with wiring and a power supply. Also, at a multi-loop site, units possessing either differing frequencies or a sequential scanning (multiplexing) feature should be employed. This avoids the expense of running loop lead-in wires in a separate conduit to avoid crosstalk.

Expenses incurred installing a sensor, aside from the electronics unit, depend upon sensor use, distance and terrain between the sensor and detection unit, communications (if any) between the detection unit and a control center, size of the total job, and the cost of local labor.

b. POWER

Most detectors are built to operate on 115 vac. The option of a 220 vac unit is usually available. Plug-in board units normally require 12 to 24 vdc. Two companies, Decatur and Indicator Controls, market a detector which operates on 12 vac. These units are usually used by small businesses to avoid meeting UL specifications, and are not considered appropriate for RVG projects.

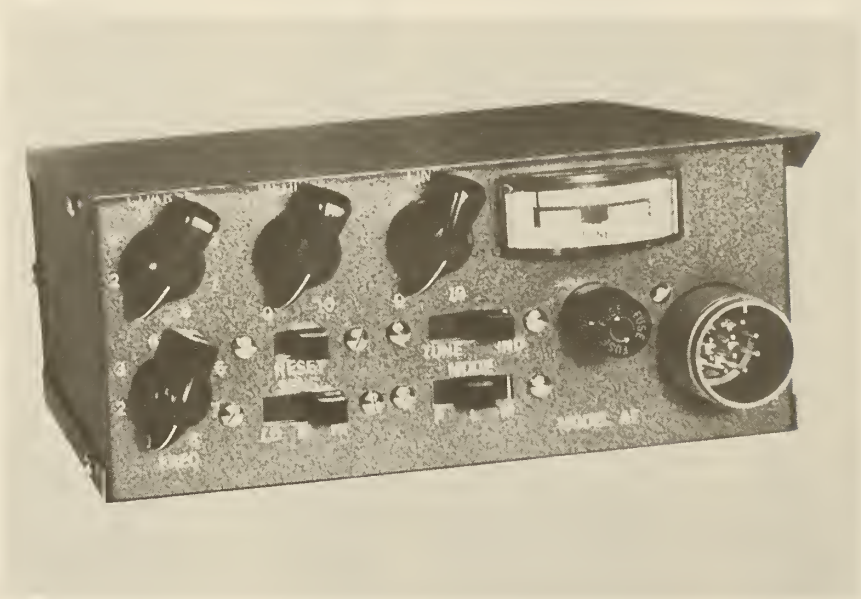
Power consumption does not incur significant expense. Most detectors use between one and five watts per channel. Five watts at five cents per kilowatt-hour costs only $2.20 per year.

c. DETECTOR HOUSING

Occasionally size or shape will play a part in the choice of a unit. All units mentioned are designed to be used inside a weatherproof cabinet. Detectors, shelves, and cabinets should be chosen to allow for ample working room within the cabinet. When numerous detector electronics are housed in one cabinet, multichannel and/or plug-in board units should be considered.

Figures 3 through 6 show popular detector models. Most models have all controls located on the front face for convenience. All case models, except Enerco models, have convenient front face electrical connection plugs. Case units can be stacked vertically and horizontally with very little servicing inconvenience.

TRAFFIC DATA SYSTEMS' LD 328

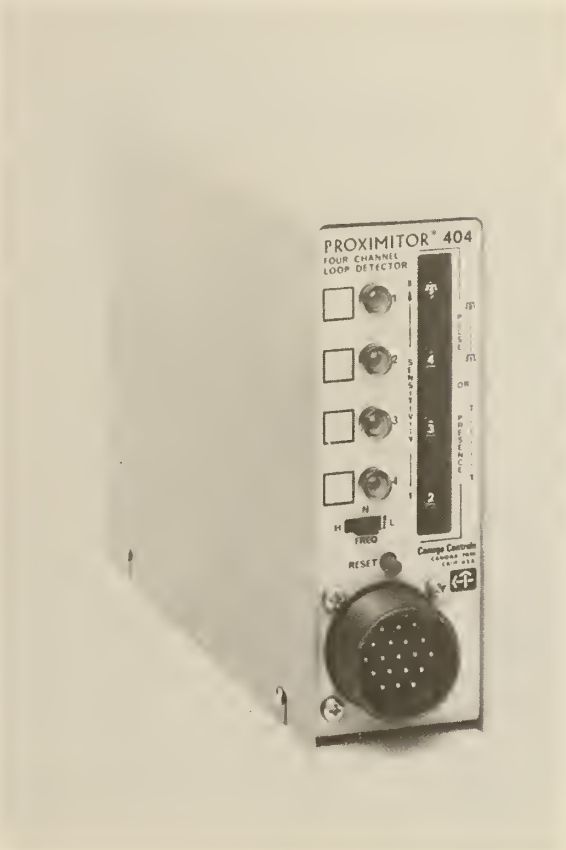


DECATUR'S MODEL AF

Figure 3. Analog Loop Detectors

SARASOTA'S 215B

Figure 3. Analog Loop Detectors (continued)



CANOGA'S PROXIMITOR 404

ENERCO'S MODEL 122

Figure 4. Digital Loop Detectors

INDICATOR CONTROLS' MODEL 3010-8A

Figure 4. Digital Loop Detectors (continued)

EAGLES' MODEL EV5

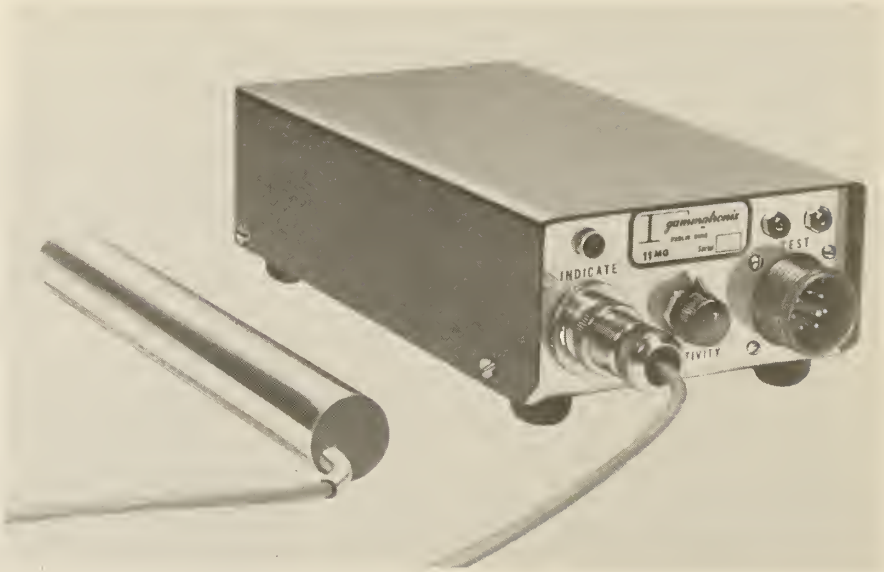
AUTOMATIC SIGNALS' MODEL MR 10

Figure 5. Magnetic Detectors

DECATUR'S MODEL DEM-3

Figure 5. Magnetic Detectors (continued)

CANOGA'S PROXIMITOR 222



GAMMATRONIX 11 MG

Figure 6. Magnetometers

d. EASE OF INSTALLATION

Installation of encased detectors consists of simply wiring the harness, connecting it to the electronics unit, and tuning the unit. An MS-type connector between harness and unit is standard, although some manufacturers offer other types optionally. Installation of plug-in board units is comparably simple, but requires installing a frame in the cabinet.

Tuning the detector is the only manner in which installation significantly differs from one unit to the next. About half of the units on the market have an automatic self-tuning feature. These units are simply turned on. Tuning occurs automatically, taking from one to 20 seconds.

Other units must be tuned manually. This normally takes about one minute and involves rotating a single switch to the correct position as indicated by an incandescent lamp or LED. The latter, if sufficiently bright for field use, is preferably due to its long life. Two Decatur models have a three-switch tuning system and an optional tuning meter in place of the lamp.

As previously mentioned, having all controls and connections on the face of the unit is very convenient. An additional convenience which Canoga and Enerco provide is space on the face of multichannel units to pencil-in the location of the loop(s) associated with each channel.

e. FUNCTIONAL PERFORMANCE

Detector electronics should be chosen to best match the intended function of the sensor, as described in the following paragraphs.

A detector used solely for the purpose of counting volume should be operated in the pulse mode. Magnetic detectors, having no presence mode, can only be used for this purpose. After receiving the pulse from one vehicle, the register is cleared and immediately able to receive another pulse. In this way, one electronics unit can accurately determine total roadway volume from a sensor located in each of several lanes.

A detector used to measure other parameters as well as volume must operate in the presence mode. To assure accurate counts at such sites, each sensor must have its own amplifier channel.

To provide accurate occupancy measurements, the electronics should have rapid and consistent pick up and drop-out characteristics. Traffic Data Systems offers optional circuits specially designed to meet requirements of traffic surveillance via vehicle counting.

There are two techniques for measuring vehicle speed. A single sensor can yield averaged vehicle speeds if an average vehicle length is assumed. Speed measurements of this type have accuracy requirements similar to that of occupancy measurements. The second technique uses a second detector slightly downstream

from the first. Speed is a function of the time difference between pulses from each detector. Both amplifiers must have equal pickup characteristics. The latter technique is more accurate.

If detectors in the speed trap arrangement are operating in the presence mode, vehicle length can be calculated and used to determine vehicle classification. Streeter-Amet manufactures a two-channel unit conveniently used to calculate vehicle size. Also, Indicator Controls and Streeter-Amet manufacture units which can output both pulse and presence simultaneously. Such units can be used to operate an onsite counter while sending presence data to a computing facility, or to send both measurements to a microprocessor.

A sophisticated visibility system makes maximum use of each sensor. Therefore, each one should be connected to its own amplifier channel, which should be operated in the presence mode. Only in this way can volume, occupancy, and speed, the three most relevant parameters, be determined.

Several companies manufacture units equipped with extension and/or delayed output functions. These are intended for use in traffic signal control. No useful purpose has been found for such features in RVG systems.

f. SENSITIVITY

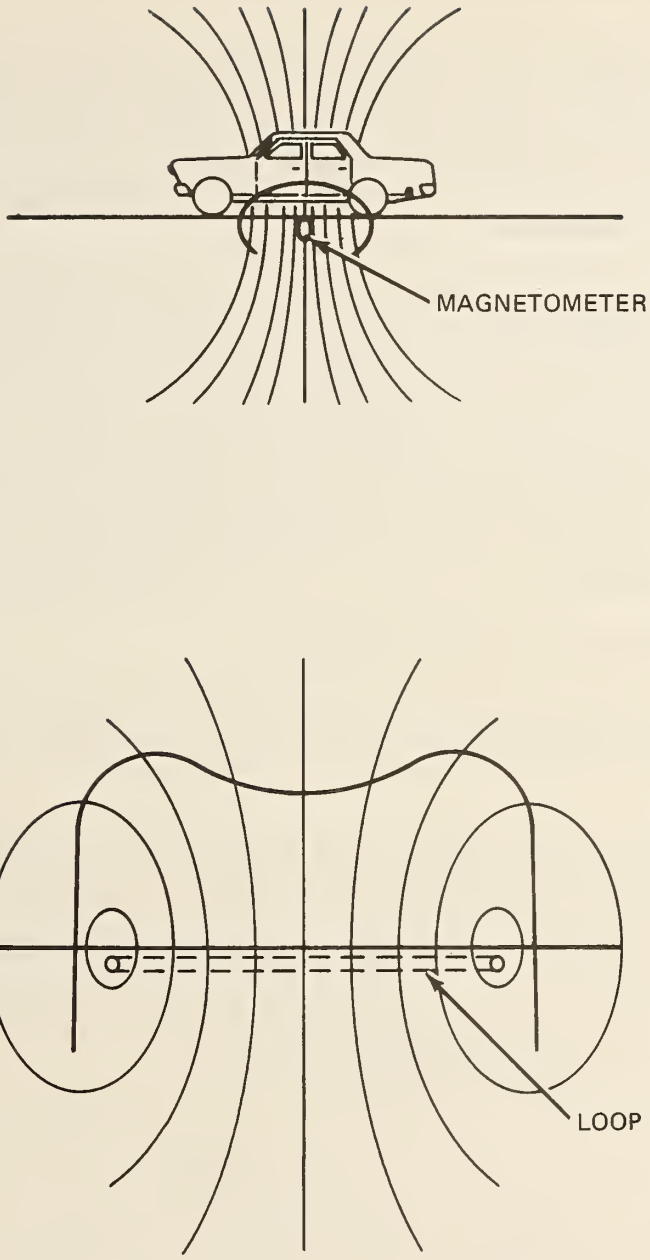
A vehicle sensor must not only be matched to the function it is to perform, but must be adjusted to the proper level of sensitivity. A sensor, properly set, will register vehicles in the sensor's lane(s) and will not register vehicles in adjacent lanes. This is more easily accomplished with some models than with others.

In general, inductive loops have a more positively defined area of influence than magnetometers. A standard six-foot (1.8 m) square loop centered in a ten to 12 foot (3 m to 3.7 m) lane does an excellent job of detecting small vehicles in that lane, while not detecting large vehicles in adjacent lanes. Most loop electronics units have three sensitivity settings which satisfactorily cover the required range of short through long loop lead-ins.

Magnetometer probes have a more spherical area of influence than loop detectors (see Figure 7). This results from the fact that a magnetometer detects flux density increases in the earth's magnetic field, while a loop detects changes in its own inductive field. Magnetometers employ a continuous sensitivity range to optimally tune out adjacent lane traffic while picking up the intended lane traffic. Probe depth also plays a sensitivity role. If a probe is located too deep, sensitivity may be too low. If located too shallow, vehicles moving slower than 20 mph (35 km/hr) may be double counted.

g. ADVANCED TECHNOLOGY

The most technically advanced sensors on the market are the digital loop detectors manufactured by Enerco, Canoga, and Indicator Controls. The Enerco models have eight or 16 channels and are not cost effective unless most of the



NOTE: MAGNETOMETER (ABOVE) HAS A SPHERICAL AREA OF INFLUENCE; INFLUENCE AREA OF LOOP (BELOW) IS MORE RECTANGULAR.

Figure 7. Sensor Placement Cross-Section

channels are used. They were designed primarily for intersection control and are not likely to find much use in visibility systems where detector locations are not bunched together.

Enerco pioneered an important multi-loop processing technique which polls each sensor sequentially, thus eliminating crosstalk between channels. Canoga uses this sequential scanning technique on their two and four channel models. Indicator Controls uses discrete frequencies on each channel to eliminate crosstalk. (Conventional analog multichannel units and single units in close physical proximity of each other also use this technique.)

One requirement of sequential scanning is that each channel must be frequently scanned to obtain accurate data. A six foot (1.8 m) square loop must be polled at least seven times per second to guarantee detection of a small car traveling at 55 mph (88 km/hr). To obtain approximate occupancy or speed data, the loop should be polled three times as often. Scanning every four loops 20 times per second allows a 12.5 millisecond channel measurement time period. A potential problem arises from the fact that sensitivity is directly related to channel measurement time. Figure 8 shows this relationship for a typical Canoga detector. Depending upon the proposed loop and lead-in configurations, difficulty may be encountered in attempting to maintain adequately high sensitivity while minimizing channel measurement times.

h. MAINTENANCE AND RELIABILITY

Modern detector amplifiers can be relied on to provide years of satisfactory service. Recently adopted features which virtually eliminate the need for maintenance are:

- Automatic self-tracking. Those units which automatically self-tune also automatically self-track. As the natural frequency of the loop drifts due to environmental changes, the detector will remain in tune. Several manufacturers provide a five percent drift-compensating circuit which performs a similar function, but with a smaller tracking range. Those units which are not self-tracking or drift-compensating require periodic retuning by maintenance personnel. Depending on the environment of the loop, one to four checks per year suffice.

- Automatic power-out recovery. Most units automatically return to an in-tune and operating state after having gone through a power outage.

- Lightning protection. Most units are protected from voltage surges on the power input lines. Some Decatur models are also protected from surges on the loop lead-ins. Fuses are normally employed, but Canoga units use a more convenient circuit breaker.

- Grounded loop operation. Canoga units can function normally even when the loop has become grounded.

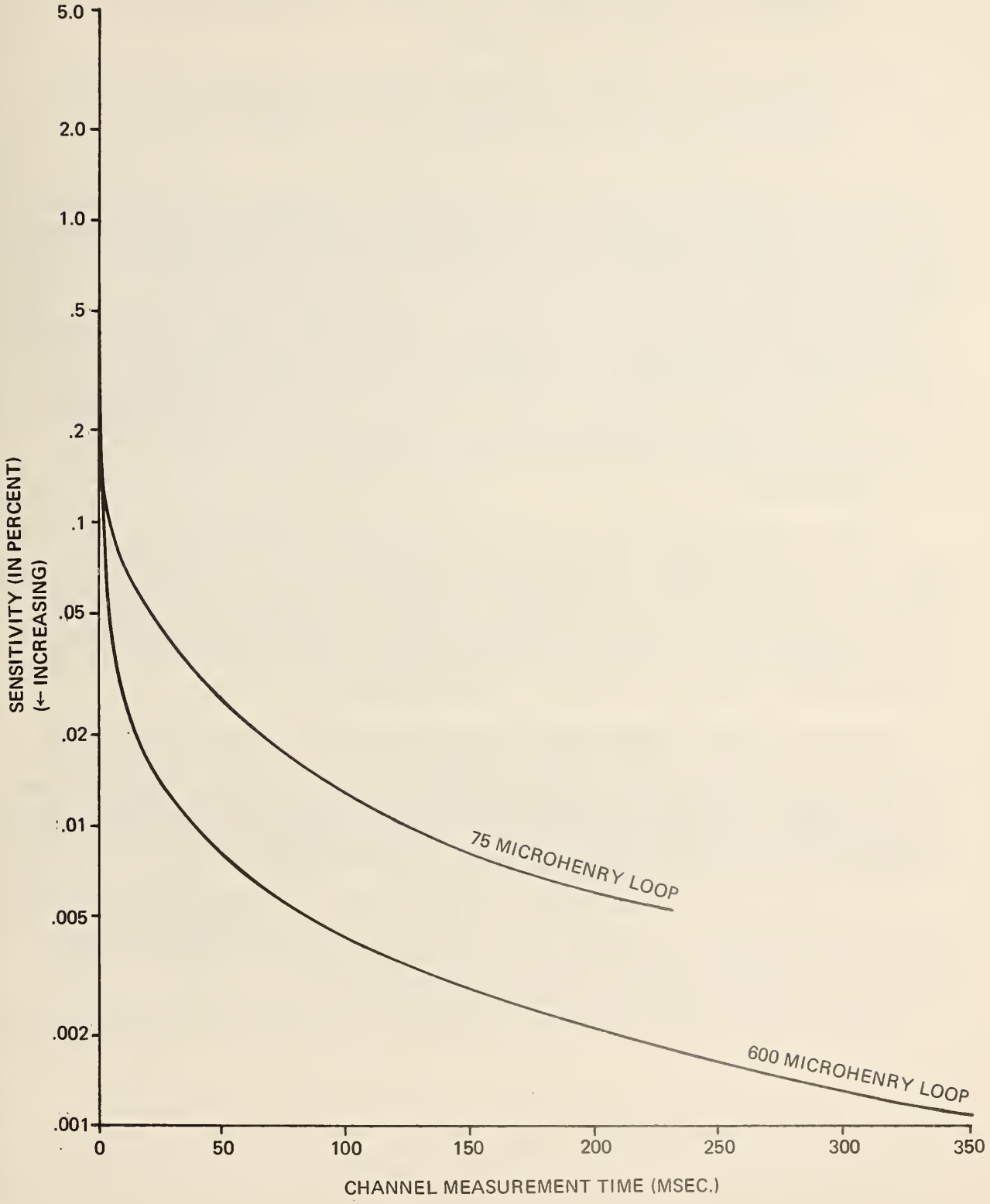


Figure 8. Sensitivity vs. Channel Measurement Time for a Canoga Proximeter 202 Sequential Scanning Digital Detector.

- Failure alert. Most units transmit a steady mark if an open loop, shorted loop, or power outage are detected. Canoga units optionally transmit a continuous flashing mark.

- Environmental tolerance. All amplifier units have a wide temperature operating range. They are designed to function properly in any vented weatherproof cabinet. In some hotter climates, cabinet fans may be needed to maintain an operable temperature.

Magnetometer probes, if properly installed, are generally more durable than loops. Loops which have broken due to buckling or cracking pavement must either be spliced or totally replaced. If a loop must be installed in suspect asphalt, burying it in one inch (2.54 cm) nonmetallic conduit will increase its lifespan tremendously.

The remaining equipment of the sensor system, conduit, cable, and communications can be troublesome or maintenance-free, depending on the quality of the initial installation. In a salty environment (near the sea or on salted winter roads), corrosion can ruin sensor and other system hardware within a year of installation. Stainless steel and other non-corrosive equipment must be used at such locations.

4-6 CONCLUSION

Vehicle sensors are generally not an essential part of RVG systems. However, their use can greatly expand the versatility of both large and small systems by providing motorists and system controllers with useful information. The driver can be advised of congestion or slow moving traffic ahead. The controller can benefit by knowing road volume, occupancy, speed, and vehicle classification. Vehicle sensors currently find their greatest use in sophisticated systems designed to provide multiple warning, guidance, and/or diversion functions.

Inductive loop and magnetometer detectors seem to be the most useful types of sensors. Loop detector technology is advancing more rapidly than magnetometer technology, and a wider variety of loop amplifiers is on the market. Most state and municipal traffic departments are familiar with loop installation and operation. Loop detectors are therefore recommended for use in RVG systems. However, specific situations may arise in which other detector types are warranted.

Choosing the best detector model for a given situation requires determining the function the unit will need to perform, and analyzing the specifications of the units on the market. Manufacturers who are being considered can be contacted for their assistance in choosing the proper model and quoting a price.

Section 5

VISUAL SIGNING

5-1 INTRODUCTION

Visual signing is virtually a required element for RVG systems. The primary purpose of RVG systems is to provide the motorist with useful information, and most systems employ some form of visual signing to do so. Signs can be either fixed or changeable (variable). Variable message signs are manufactured in numerous sizes, shapes, and degrees of sophistication. This section will discuss the types of signs available for use in RVG systems and the criteria that can be applied to evaluate them. First, the objectives of visual signing as applied in RVG systems will be discussed.

5-2 SIGNING OBJECTIVES

RVG systems can assist motorists by providing warning, guidance, and diversionary information. Of these, signs can provide the warning and diversionary messages. Specific objectives may include:

- Informing the motorist of the existence of the RVG system
- Warning the motorist of reduced visibility conditions
- Advising the motorist to take preventive action (i.e. reduce speed)
- Directing the motorist to divert.

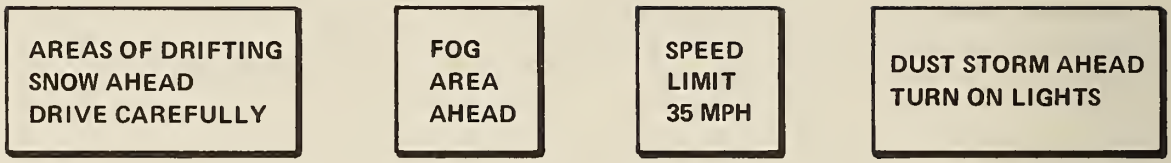
Examples of visibility-related warning messages are displayed in Figure 9.

In order to fulfill its purpose, a sign must attract the motorist's attention through proper location and visual appearance. The sign must quickly convey its message using clear, visible lettering and concise wording. Finally, it must display a relevant and proper message. Different types of signs employ different techniques to attain the objectives with varying degrees of success.

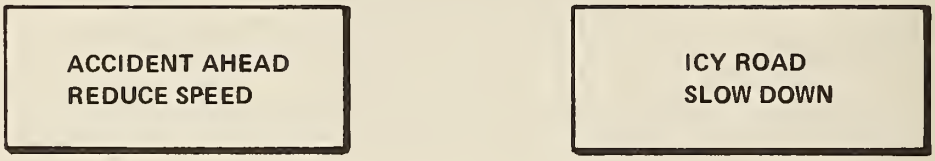
5-3 SIGN TYPES

Two general categories of message signs can be employed in RVG systems: fixed and changeable signs; both categories can be further subdivided into various candidate types.

VISIBILITY – RELATED WARNING MESSAGES:



HAZARD MESSAGES USED IN SOPHISTICATED RVG SYSTEMS:



DIVERSIONARY MESSAGES:

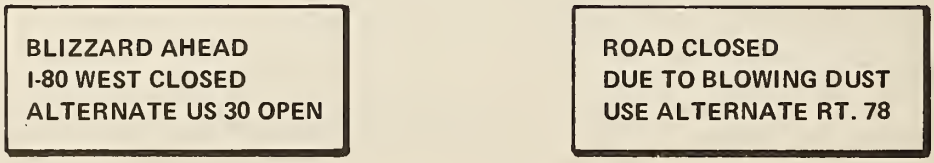


Figure 9. Examples of RVG System Motorist Advisories

a. FIXED SIGNS

Fixed message signs include the following three types.

1. Basic Fixed Message Sign

This sign type can take on a variety of forms. Basically, it is a sign panel of some regular shape that contains a fixed message and is generally always exposed to the motorist. Fixed message signs can serve to complement the operation of RVG systems by apprising the motorist of the system. For example, this type of sign can be placed just outside the physical boundaries of an existing RVG warning system. Fixed message signs are often used by highway organizations to identify zones along the roadway prone to visibility hazards. Example messages used are FOG AREA AHEAD or FOG AREA NEXT TEN MILES. Major disadvantages associated with fixed message warning and advisory signs are that they are passive in nature and, therefore, present a credibility problem to the motorist. In addition, the legibility of fixed message signs is generally inferior to changeable message signs, particularly in a reduced visibility environment.

2. Fixed Message Sign with Flashing Lights or Beacons

Fixed message signs with flashing lights or beacons are used by many agencies to warn and/or advise motorists of potential problems caused by such conditions as fog, blizzards, or blowing dust. The flashing lights or beacons are generally mounted alongside the fixed message and are actuated whenever a visibility problem exists. This sign type tends to reduce the credibility problem associated with fixed signs. A typical message reads, FOG AHEAD WHEN FLASHING. Although flashing lights and beacons are readily visible under conditions of reduced visibility, the actual message, if not illuminated, lacks legibility.

3. Movable Fixed Message Sign

Included in this category are a variety of signs upon which fixed messages are imprinted, displayed, and removed manually by designated personnel. Messages are typically the same as those of a standard fixed sign. Other characteristics are also similar with the possible exception of credibility, which increases with the frequency of posting and removal of the sign. A portable tripod supported sign placed on the road shoulder during a few hours of early morning fog commands more respect than a sign which highway maintenance personnel post seasonally. Of intermediate credibility, are the small status type signs often used by turnpike authorities which slide into and out of homemade frames at toll plazas. On occasion, a removable fixed message sign will incorporate the use of flashing lights. Where the fog condition is not static but moves about, it is very difficult to keep the sign in the proper location.

With few exceptions, fixed message signs are manufactured in-house (i.e., by the eventual user of the sign). Major manufacturers may supply materials such as reflective sheeting, but they do not attempt to market the total fixed message sign.

b. CHANGEABLE MESSAGE SIGNS

The vast majority of changeable (variable) message signs available for use in RVG systems is manufactured by approximately 14 companies. Table 3 lists these companies and the types of signs they offer. The following paragraphs describe the various types.

TABLE 3. SUMMARY OF VARIABLE MESSAGE SIGN TYPES

	Sign Type					
Sign Manufacturers	Lamp Matrix	Disc or Vane Matrix	Drum	Scroll	Hinged Panel	Fiberoptics
American Sign & Indicator Co., Spokane, Wash.	●					
Dietz Co., Syracuse, N.Y.	●					
Display Technology, Los Altos, Ca.		●				
Federal Sign & Signal, Downers Grove, Ill.	●					
Fosco, Dixon, Ill.	*		●	●		
Information Concepts, N.Y., N.Y.		●				
Rank Precision, N.Y., N.Y.						●
Rhodes & Maine, Fullerton, Ca.	●					
Solari America, N.Y.				●		
Traffic Control Systems, Colorado Spr., Colo.				●		
Valtec Corp., West Boylston, Mass.						●
Varicom 3M, St. Paul, Minn.					●	
VePed, Oklahoma City, Ok.					●	
Winkomatic, Avon Lake, Ohio	●		●			

*May soon enter market

1. Lamp Matrix Sign

The variable message lamp matrix sign has been widely used in highway traffic operations. It is manufactured in a wide variety of sizes large enough for highway use, and in portable, trailer mounted models. A large portion of the frontal display area is usable message area.

The sign display generally consists of a number of individual character modules mounted side-by-side in a metal housing. Each of the modules utilizes an array of incandescent lamps, usually 35 (seven rows of five bulbs each) to form each character. Horizontally-louvered sun-screens may be used to ensure readibility and prevent phantom images caused by sunlight shining directly onto the sign face during dawn and twilight hours. Figure 10 shows a cross-section of a lamp matrix sign. Figure 11 shows photographs of several typical lamp matrix signs.

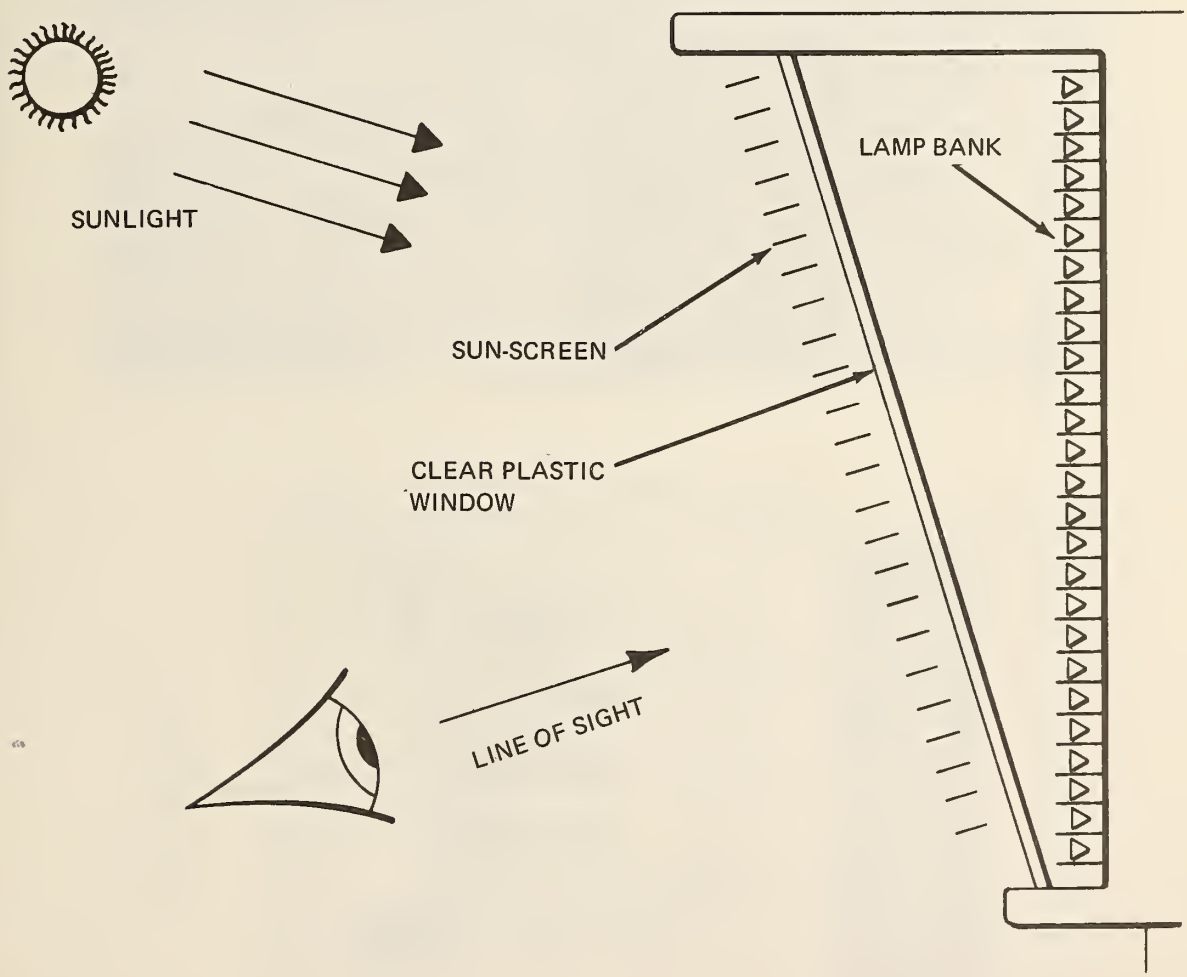
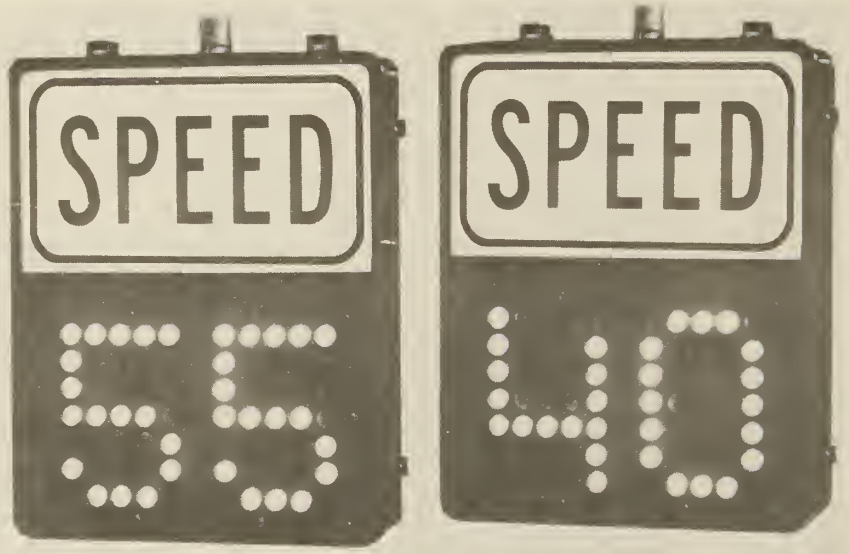


Figure 10. Typical Lamp Matrix Sign - Side View

DIETZ COMPANY,
TRAFFIC DIRECTOR



WINKOMATIC VARIABLE MATRIX SPEED SIGN

Figure 11. Typical Lamp Matrix Signs

WINKOMATIC VARIABLE MESSAGE SIGN

Figure 11. Typical Lamp Matrix Signs (continued)

2. Electromagnetic Disc Matrix Sign

Disc matrix signs produce messages in a similar manner as lamp matrix signs, except they use reflective discs in place of lamps. Each character (letter, number, etc.) is formed by a matrix (typically five by seven) of flat, circular, metallic discs. The discs are coated with the sign background color on one side and with a contrasting reflective material on the other. The discs are pivoted and flipped from one side to another by magnetic action. The sign must be externally lighted in a manner similar to a fixed highway guide sign. Outdoor versions of this type of sign are relatively new in development, but their use is rapidly increasing. Figure 12 shows operating characteristics of the disc matrix sign. Figure 13 shows a sign in use on the I-80 RVG system in Wyoming.

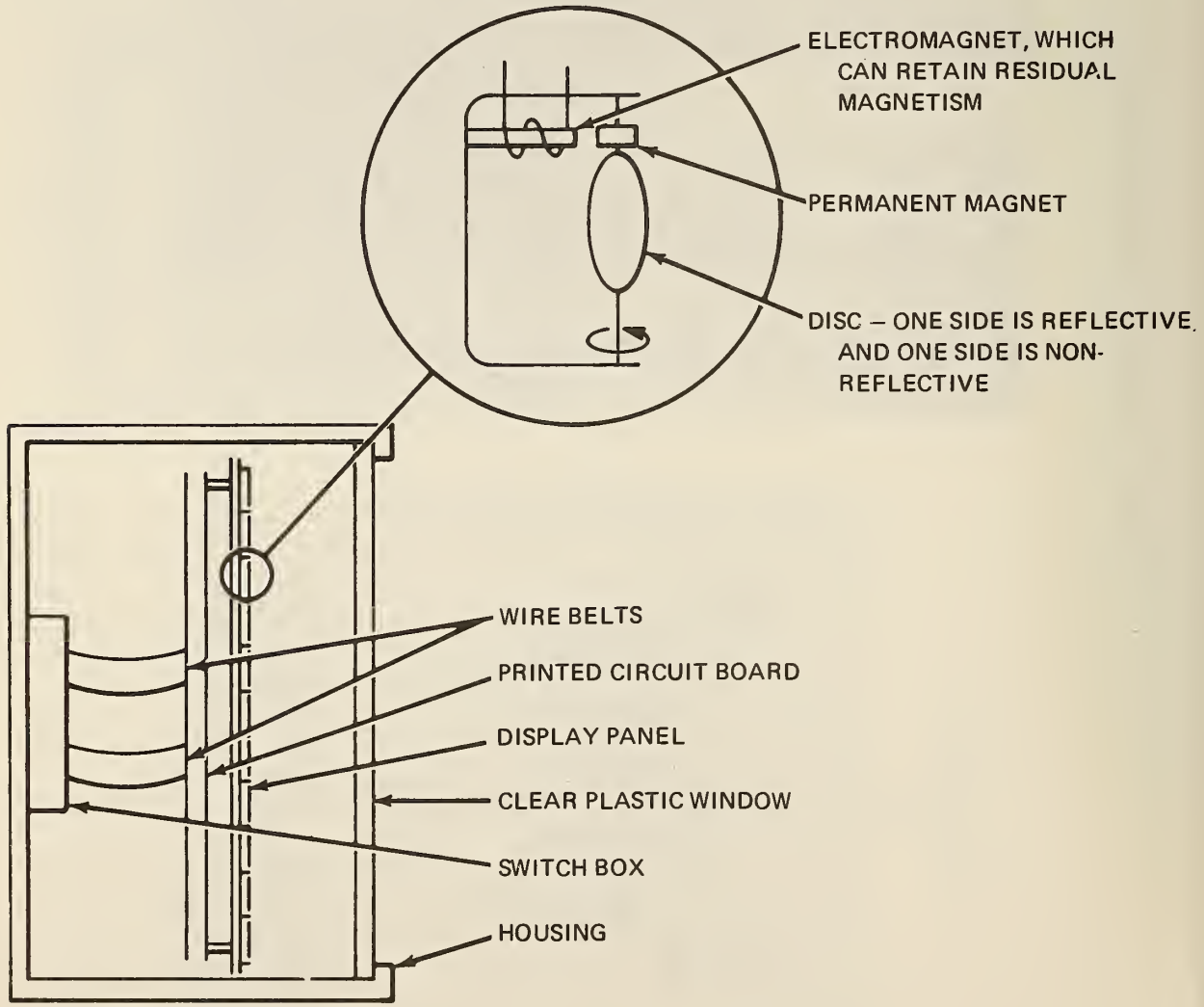


Figure 12. Typical Disc Matrix Sign - Sign View

Figure 13. Disc Matrix Sign by ICI, Installed on Wyoming's I-80 RVG System

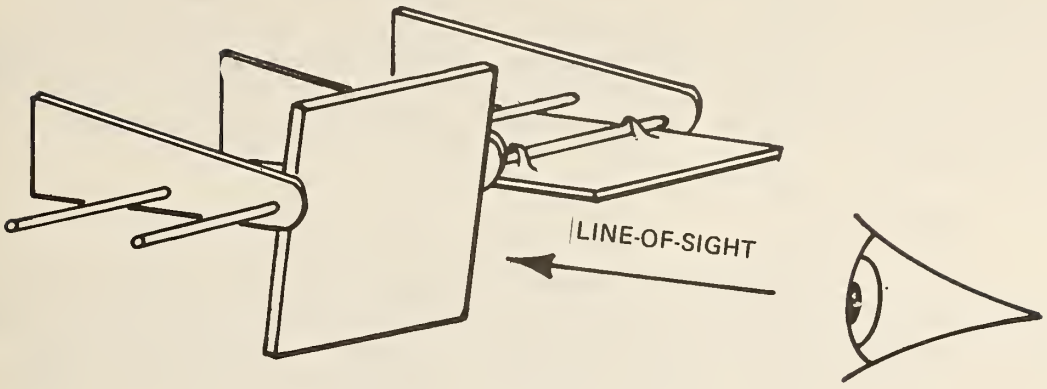
3. Electrostatic Vane Matrix Sign

This sign (also called a wafer or flag matrix sign) uses electrostatically-controlled vanes to form a desired message. Each half-inch square (1.61 cm^2) vane is moved into one of two positions: erased (hidden from view) or written (in view). The sign face is made up of modules. Each module has a specified number of vanes (typically 100). The modules fit closely together, horizontally and vertically. Therefore, signs of this type may be almost any size, single or double-sided, and characters are not limited to certain locations. A character may cross module boundaries and be any size or shape. Thus, this sign offers complete flexibility, since any type of message can be displayed on the sign.

The sign display is passive; that is, it does not emit light, but instead, controls the passage and reflection of light. The sign uses ambient and artificial light to produce displays visible to the motorist under normal lighting conditions. Figure 14 shows a vane matrix sign operating in California. Figure 15 shows the operating mechanism of the sign.

Figure 14. Vane Matrix Sign by Display Technology, Installed on Route 88 in California

EXAMPLE OF OPENED AND CLOSED VANE:



SIDE VIEW DRAWING:

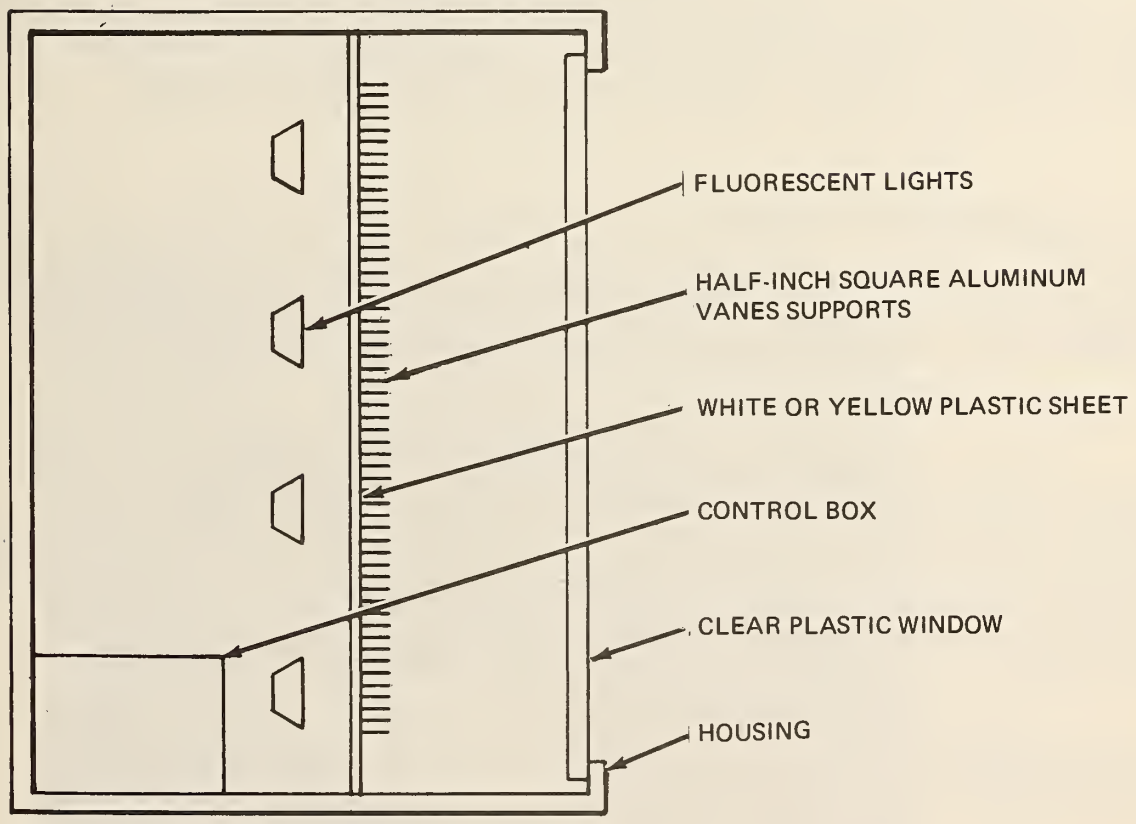


Figure 15. Typical Vane Matrix Sign (VMS)

4. Rotating Drum Sign

These signs are composed of multi-faced rotating drums which have messages imprinted on each face. The message capability is thus limited to the number of faces on the rotating drum (usually three to six). The drums come in numerous sizes and can be stacked vertically for multi-line messages. The messages can be displayed in whatever color or form desired. Figure 16 shows a cross-section drawing of a multi-line drum sign. Figure 17 shows a similar sign as it would appear to the motorist.

5. Scroll Sign

These signs make use of a continuous belt upon which are attached a number of message panels. The belt is stretched across the sign face between two storage drums rolled until the desired message is displayed. In general, this type of sign offers maximum flexibility in message formatting. Figure 18 shows scroll signs in operation. Figure 19 shows the operating mechanism of the sign.

6. Hinged Panel

This type of sign uses a small motor to swing two hinged panels across the face of a standard reflectorized sheet metal sign. The panels have two possible positions, allowing a maximum of two messages, or one message and one blankout. Figure 20 shows an example of the sign in use and the working mechanism.

7. Fiberoptics

Techniques for adopting fiberoptics to variable message signs are still under development. Several manufacturers presently offer a sign with two-message capability. One manufacturer is developing a message sign with practically unlimited flexibility, using fiberoptics. There are not enough examples of this sign type used for traffic control purposes to permit thorough evaluation at this time.

8. Neon

This type of sign uses neon tubing to form the letter characters. When illuminated, the characters are typically red in color, although a recent study* indicated yellow may provide a more legible message in some environments. Figure 21 shows how this sign may be designed to provide two (or more) messages; however, it becomes mechanically impractical to do so. This sign type is most suitable for small signs with one-word or speed limit messages. The signs are usually purchased locally from companies which market neon advertisement signs.

Appendix D provides detailed information about the costs and physical characteristics of variable message sign types which are marketed nationwide by leading manufacturers.

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*Florida Dept. of Transportation, Bartow Fog Testing Facility

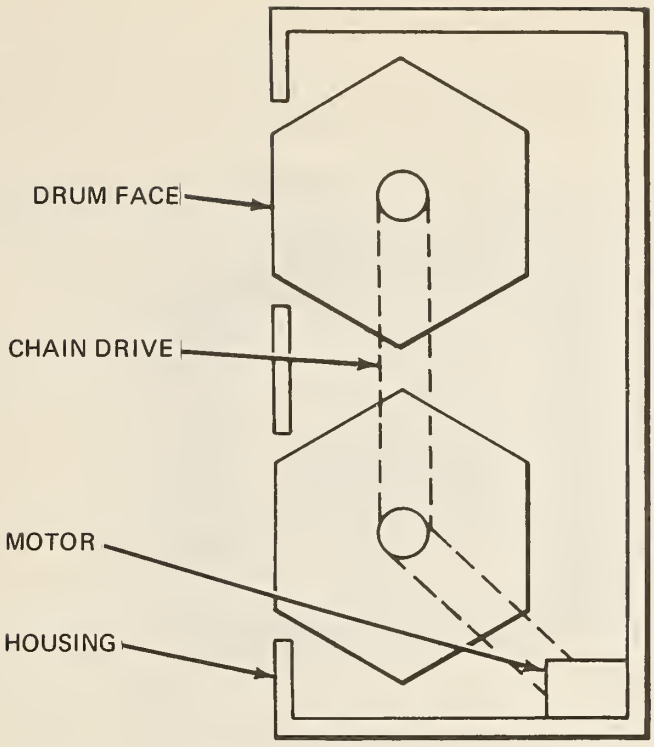


Figure 16. Rotating Drum VMS - Side View

Figure 17. Rotating Drum Sign by Fosco Fabricators

Figure 18. Scroll Sign by Solari, Installed on Freeway in Naples, Italy

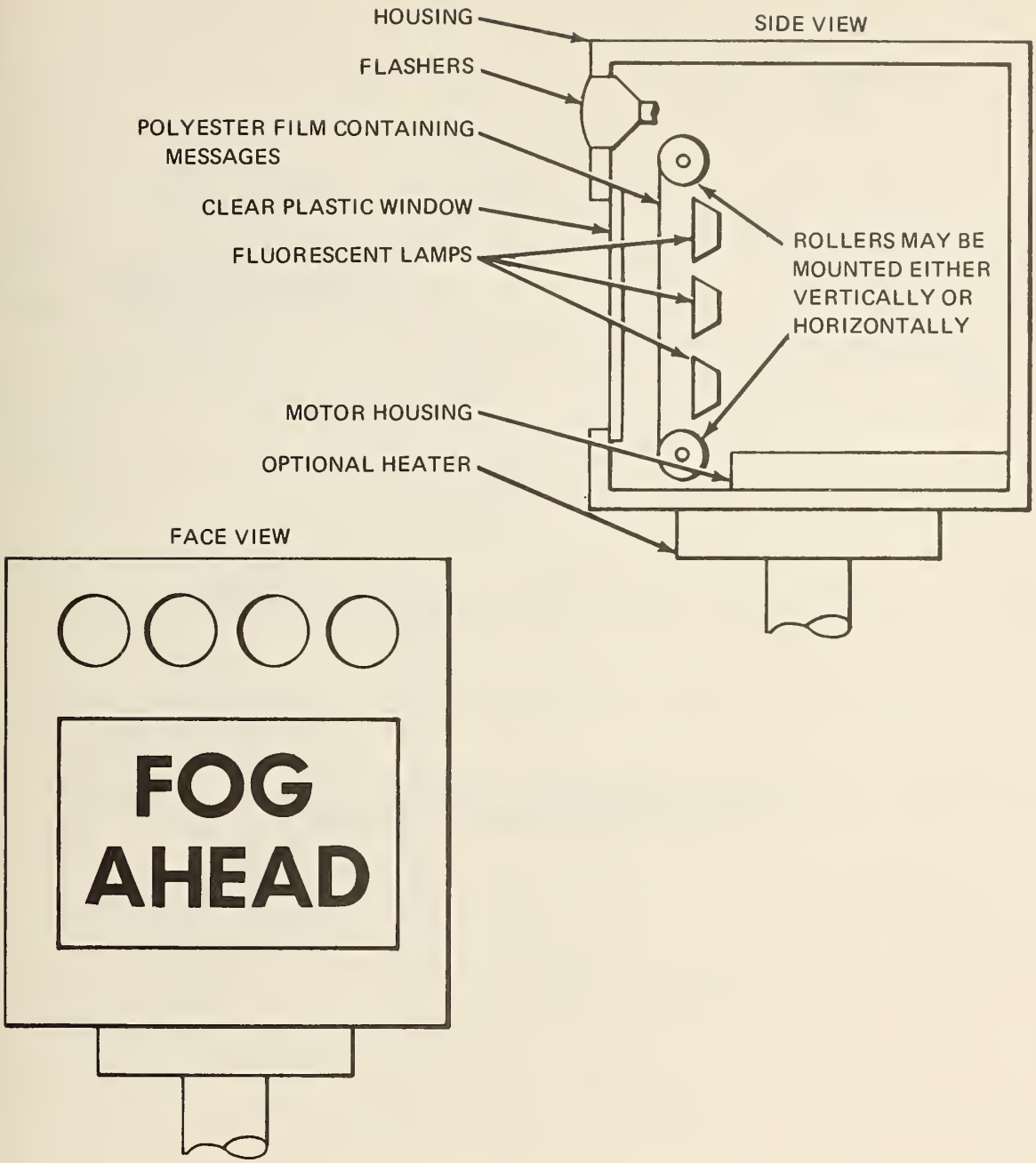
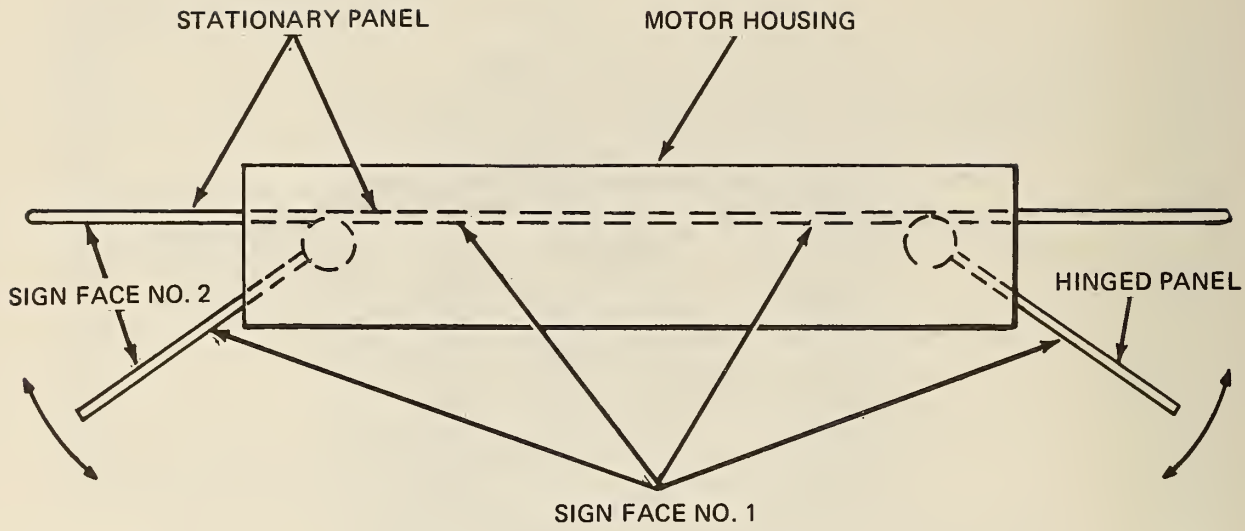


Figure 19. Scroll-Type Sign

DRAWING OF SIGN:



NOTE: BOTH HINGED PANELS SWING IN AND OUT TOGETHER

Figure 20. Typical Hinged Panel Sign

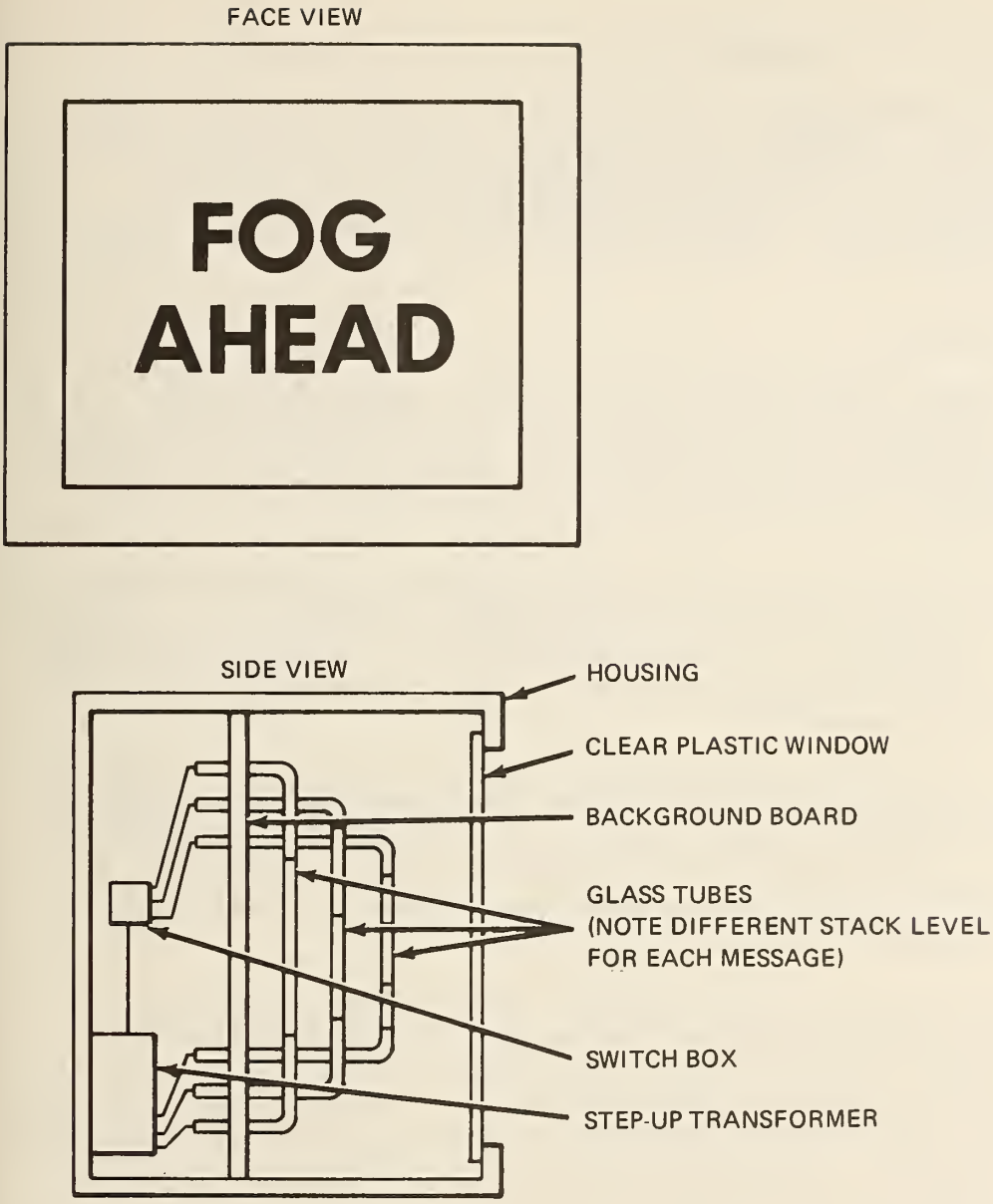


Figure 21. Neon Variable Message Sign

5-4 EVALUATION CRITERIA FOR SIGNS

There are numerous aspects to be considered in purchasing signs for RVG systems. They include legibility, maintainability, flexibility, electronic specifications, environmental tolerance, reliability (proof through usage), and cost. Table 4 offers a quick comparison of these characteristics as they are related to the various candidate sign-types. The following paragraphs discuss in detail these evaluation criteria.

a. LEGIBILITY

The first function which a sign must perform is to attract the motorist's attention. The right step in achieving this goal is to use a sign whose display resembles a highway sign and not an advertisement. Several manufacturers branched into traffic control from advertising and the appearance of their signs may tend to show their heritage.

Proper sign location can help overcome the passive appearance of a sign. Locating identical signs on each side of a roadway tends to identify them as "official" highway signs. Locating signs overhead leaves no doubt. The dual sign approach is particularly useful for small, fixed, neon, and hinged panel signs. Larger signs should utilize overhead mountings.

Flashing amber lights can help capture the motorist's attention to all types of signs. Flasher configurations generally consist of one light above the message and one below, or two lights above, one on each side. More than two flashers generally tends to detract from the message. Messages which are light-reflecting (as opposed to light-transmitting) are more difficult to discern and, therefore, have a greater need for flashers.

Sign location in relation to the reduced visibility condition may have some bearing on the type of sign chosen for a system. A sign to be located well in advance of the reduced visibility condition, and unlikely to become immersed therein, can be of the light-transmitting or light-reflecting type. However, studies have shown that a sign located within an area of poor visibility should be light-transmitting to be adequately visible. Lamp matrix and neon signs best fulfill the need, because each message character is its own light emission source. Internally illuminated signs, such as the vane matrix, drum, and scroll types, are also generally acceptable. However, with these sign types, uniform light emission from every part of each character is difficult to attain, thereby reducing the quality of displayed message.

A sign may have to be readable in direct sunlight as well as in reduced visibility conditions. In such cases, signs which rely solely on light emission (i.e., bulb matrix, neon, and fiberoptic) tend to get washed out by intense sunlight, whereas light-reflective signs may be most visible during such a condition. One technique used to prevent wash-out of bulb matrix signs is to install a louvered sunscreen on the face of the sign. While this usually serves its purpose, it also reduces the allowable viewing angle of the sign, and causes difficulty in keeping the sign face clean.

TABLE 4. GENERAL CHARACTERISTICS OF VARIABLE MESSAGE SIGN TYPES

Evaluation Criteria	Sign Type							
	Lamp Matrix	Disc Matrix	Vane Matrix	Drum	Scroll	Hinged Panel	Neon	Fixed Sign
Legibility								
Can be easily seen at 1000 feet (305 m) by motorists at 55 mph (88 km/hr)	●	●	●	●	●		●	
Looks like highway sign				●	●	●		●
Reads easily thru moderate reduced visibility	●			●	●		●	
Reads easily despite intense direct sunlight		●	●	●	●	●		●
Maintainability								
Rarely requires maintenance		●	●	●	●	●	●	●
Flexibility								
Offers message flexibility	●	●	●	●	●			
Offers format flexibility	●	●	●		●	●		
Electronics								
Has message retention feature in case of power failure		●	●	●	●	●		●
May use internal lighting	●		●	●	●		●	
May use external lighting		●	●	●	●	●		
Has sign monitor system to detect malfunctions		●	●		●			
Has low daytime power consumption		●	●	●	●	●		●
Environment								
Protected against interior dust and moisture condensation	●	●	●	●	●	●		●
Usage								
Has been widely used in traffic control systems	●			●	●		●	
Cost								
Low to intermediate			●	●	●	●	●	●
Low						●	●	●

For a lamp matrix sign to be viewed comfortably, lamp intensity must be proportional to ambient light. Lamps of fixed intensity will be either too dim to be seen in daylight or too bright to read at night. A continuous automatic dimming circuit to control lamp brightness is, therefore, highly desirable.

Just as a message should be legible when the sign is indicating an advisory, it should not appear at all when not called. This is known as a sign's blankout characteristics. Lamp, disc, and vane matrix signs can be totally blanked out, as can drum, scroll, and hinged panel signs which have a blank face. Blankout of the latter three types should not be accomplished by just turning off the illumination, because an image may still be visible. Neon tubes may still be visible after the sign is turned off, and fixed signs obviously cannot be blanked out.

b. MESSAGE FLEXIBILITY

Different sign types offer different flexibilities in regard to message formatting. Criteria of interest include message size, pictorial ability, use of colors, speed of message changes, and the ability to flash or flow messages across the display.

Basic character size and shape should be as similar as possible to the corresponding dimensions specified in the Manual on Uniform Traffic Control Devices for the type of roadway being considered. Lamp and disc matrix and drum signs come in a wide variety of sizes. Once purchased, the character size and number of characters remain fixed. The disc matrix sign manufactured by Information Concepts, Inc. offers a giant set of characters which occupy three or four normal lines of sign. In most cases, lamp and disc matrix and drum signs do not possess the ability to display pictorials.

Vane matrix and scroll signs (excluding the Traffic Control Systems scroll sign) offer complete flexibility to vary character size and display pictorials within the available space. The latter feature is not really useful for visibility warnings, but may be used during good weather conditions for other purposes.

Drum and scroll signs offer the widest flexibility in the use of color. Each message face can consist of different colors. Matrix signs are limited to displaying either white or yellow characters on a black background. Neon signs are limited to displaying fixed color(s) on a dark background.

Message changes can be affected almost instantly on lamp and vane matrix and neon signs. This can eliminate motorist confusion. These signs can flash either a single message or two alternating messages. To avoid confusing motorists, no more than two messages should be flashed alternately. Disc matrix and drum signs require a few seconds to change a message, possibly causing some confusion to the motorist.

Present off-the-shelf disc matrix signs do not have the capability to flash messages as well as lamp and vane matrix signs. Message flashing on the disc matrix is presently accomplished by flipping the message discs in a sequential flow pattern (left to right) until the displayed message has been eliminated. One disc sign manufacturer has indicated that a flashing mode feature (similar to the lamp and vane matrix) can be added to the operational functions by redesigning the sign controller.

Scroll signs also require about two seconds of change time for each frame that must be unrolled. This provides ample opportunity to confuse motorists. Turning off any internal lighting during a sign change helps. Hinged panel signs require approximately five seconds to switch from one display to the other.

Several manufacturers of lamp matrix signs offer the option of a message which flows across the display. This is generally not effective in a motorist advisory system because the motorist lacks the time needed to concentrate on the sign.

c. CONTROL SOPHISTICATION

Control of the signs discussed in this survey is exercised by a variety of means, ranging from no control at all for static signs, to control by high capability computers in the case of some large, sophisticated, variable message signs. Several sign manufacturers offer total control systems for their matrix, drum, and scroll signs. Available features include:

- Retention of message in case of power failure (backup power)
- Automatic detection of sign malfunctions
- Preprogramming of message, days in advance
- Hardcopy of displayed message
- CRT display of current message
- Ability to input new messages on-line
- Alternately flashing messages
- Flowing messages.

Less sophisticated systems may forego the use of a control center and its required communication system. Signs may be activated manually or by visibility detectors. Malfunction detection is performed visually by patrolmen or maintenance personnel.

Also, less sophisticated systems offer the advantage of lower total cost. Computerized systems offer greater flexibility. As a side benefit, computer-driven signs can display a wider variety of messages, helping the sign retain the attention of motorists.

d. ENVIRONMENTAL TOLERANCE

RVG system signs are likely to be subject to at least one environmental extreme. It may be high humidity, heavy rain, severe wind, polluted air, air saturated with dust, or high or low temperatures. To guard against the elements, electrical

signs are housed in weatherproof cabinets with acrylic or polycarbonate windows before the sign faces. (A thick screen will also help protect the sign against vandalism.) In general, sign types which cannot function properly in extreme temperature conditions can be implemented with heating or cooling devices to make them operational.

e. EXTENT OF PRESENT USAGE

The technology of variable message signs is becoming more sophisticated as the market demand increases. Several new concepts, such as the American Sign and Indicator Unex sign system and fiberoptics signs, have not yet been given thorough testing. Other sign types, (i.e., the disc and vane matrix, and hinged panel signs) have been given limited usage in traffic control to date. Their technology is also relatively new. Scroll and drum signs have been around longer and have been used in a moderate number of RVG and other traffic control systems. By far, however, the most popular variable message sign used for RVG systems has been the lamp matrix sign, particularly those manufactured by Winkomatic.

Appendix D provides locations for some of the major manufacturers' variable message sign installations.

f. COSTS

Message sign expense can be divided into the following categories:

- Purchase and installation costs
- Operational costs
- Maintenance costs.

Initial expenses can be minimized by using in-house manufactured, fixed message signs. Neon and hinged panel signs can also be purchased at reasonable prices. As the degree of sophistication of sign systems further increases, so does the price. Figure 22 shows approximate purchase prices of typical sign systems. Individual sign prices are included in Appendix D. It should be remembered that these are unit list prices and are subject to bulk order discounts and bid price reductions.

Operational expenses, if separated from maintenance costs, are proportional to electrical power consumption. Naturally, fixed messages signs without flashers or illumination cost nothing to operate, while bulb matrix signs are the most expensive to operate. Table 5 gives power consumption requirements for various types of signs. Annual operating costs can be estimated from the figures, but manufacturers should be consulted for more exact estimates when exact sign size and feature requirements are known.

Maintenance expenses encountered in different installations tend to vary. Appendix F lists comments received from agencies currently operating variable message signs in RVG systems. In most cases, maintenance is limited to scheduled checkups, and, in the case of lamp matrix signs, bulb replacements. Table 6 lists manufacturers bulb life expectancies.

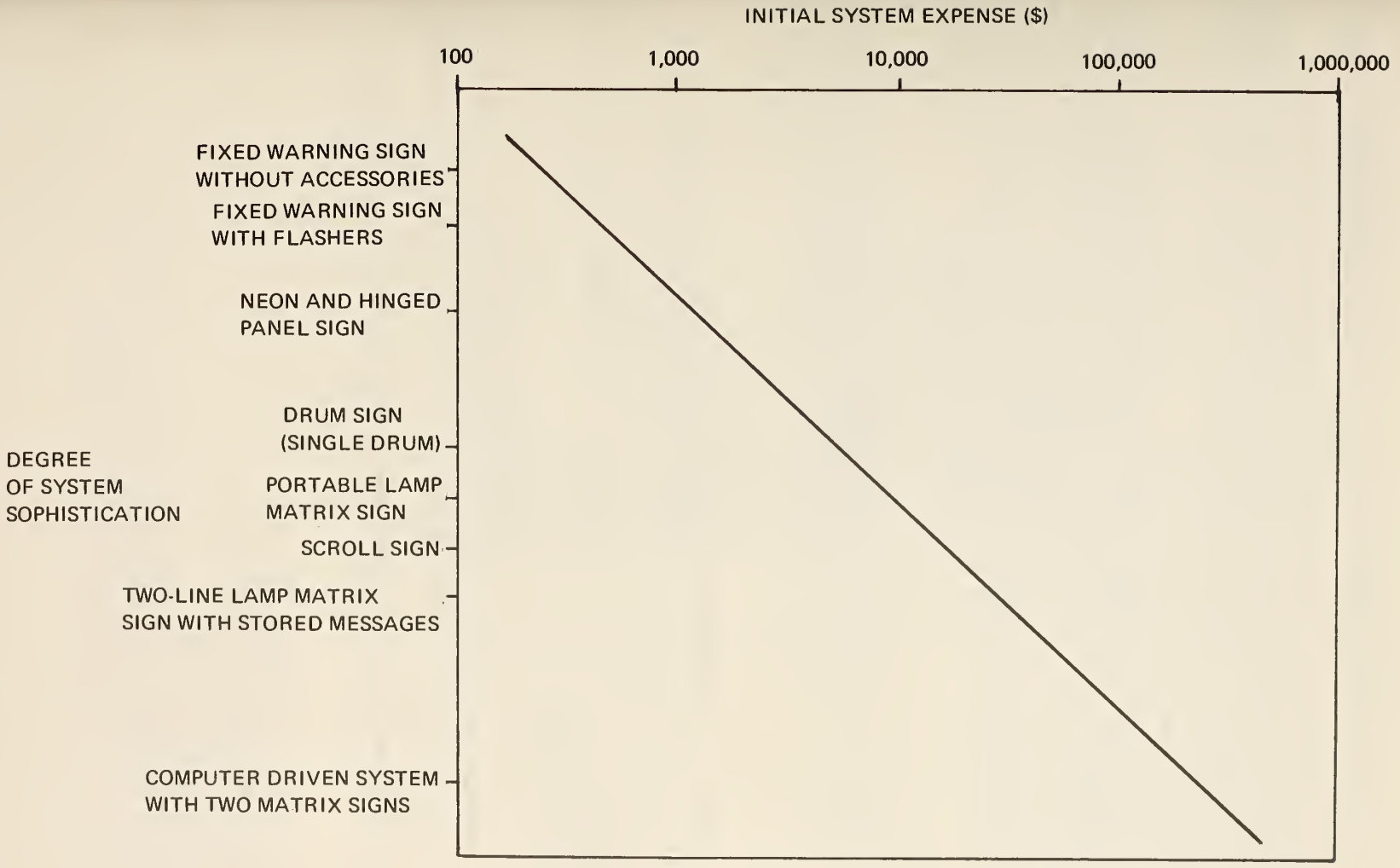


Figure 22. Typical Prices for Fixed and Variable Message Signs

TABLE 5. APPROXIMATE POWER REQUIREMENTS FOR VARIOUS SIGN TYPES

Sign Type	Power Requirement
Fixed Sign, No Flashers	0 kilowatts (kw)
Flashers (two alternating)	0.1 - 0.2 kw
Neon	0.2 kw for 8 letters, 10 inches (25.4 cm) high
Hinged Panel	0.4 kw during face change 0 kw other times
Scroll	0.2 kw during face change 0.15 - 0.35 kw for internal lighting 0.4 - 1.2 kw for heating if needed
Drum	0.5 - 1.0 kw during face change 0.15 - 0.5 kw/drum for heating if necessary 0.3 - 1.0 kw for external lighting
Vane Matrix	.05 - 0.1 kw for control unit 0.1 - 0.4 kw for lighting
Disc Matrix	0.7 kw for control unit and heater or blower 0.6 kw for external lighting
Portable Bulb Matrix	1.0 to 1.5 kw for typical message 2.0 kw max.
Bulb Matrix	11 to 15 watts/bulb (approximately 2.0 to 5.0 kw/typical single line)

Notes

Annual Cost = Σ Power Requirement Type (kw) x cost per kilowatt-hour x number of hours per year

Example

Maximum cost for a two-drum sign which:

- Undergoes face changing 20 hours per year
- Is illuminated 4,000 hours per year
- Is heated 2,000 hours per year
- Assumes cost of electrical power = $0.05 per kilowatt-hour
- Is (1.0 kw) ($0.05/kw-hr) (20 hrs/yr) + (2 drums x 0.5 kw/drum) ($0.05/kw-hr) (2,000 hrs/yr) + (1.0 kw) ($0.05/kw-hr) (4,000 hrs/yr) = $301/yr.

g. CONCLUSION

The ultimate goal of any RVG system is to provide motorists facing poor visibility conditions with information they can use to make their driving safer, more efficient, and more comfortable. Visual signs have the versatility to provide much of the needed information, including warning, advisory, and diversionary messages.

Signs can be of either fixed or variable type. Both have their place in RVG systems. Fixed message signs may serve to advise motorists of the existence of an RVG system or to warn them of possible reduced visibility conditions when no real-time condition detection system is available. Variable signs can provide current relevant visibility information through the use of an active detection system. They can also be used for other types of messages. When there is a choice, variable message signs are to be preferred because of their increased usefulness, credibility, and flexibility. However, they are generally much more expensive than fixed signs.

Of the several types of variable message signs studied, all had their own unique set of advantages and disadvantages. The needs and restraints of any proposed RVG system must be compared with the attributes and faults of the various sign types and manufacturers to determine the best sign products to be used in the system.

TABLE 6. ADVERTISED BULB LIFE BY SIGN MANUFACTURER

Sign Manufacturer	Advertised Bulb Life (Hours)
Winkomatic	10,000 at max. intensity 40,000 at min. intensity 20,000 average
Rhodes & Maine (Portable signs)	10,000 minimum
Dietz (Portable signs)	3,000 minimum

Section 6

REDUCED VISIBILITY GUIDANCE AND DELINEATION

6-1 INTRODUCTION

Highway Guidance Equipment herein includes all forms of passive roadway delineation (paints, thermoplastic strips, reflectors, raised pavement markers, etc.) as well as some forms of active guidance, such as inset pavement lights and median-mounted strobe lights.

The variety of such devices, the conditions of their use, and the details of their cost effectiveness constitute a mass of information difficult to summarize.

Three important documents represent landmarks in the field. NCHRP Report 130 (Roadway Delineation Systems, 1972) provides enormous amounts of detailed information on information requirements, delineation situations, human factors, types of equipment, and purchase, installation, and maintenance costs. It also provides useful guidelines for decision making.

A recent DOT report (State of the Art on Roadway Delineation Systems, FHWA-RD-76-73, 1976) reviews and updates some of the findings of the above report, and summarizes the cost and effectiveness of currently available delineators. This study is concerned with three broad categories of delineation: pavement markings, post delineators, and raised pavement markers.

A report, recently issued by FHWA (Optimization of Traffic Lane Delineation, FHWA-TS-77-200, 1977) reviews and evaluates existing delineation practices, investigates initial and maintenance costs, and recommends an optimum system. Recommendations (meant primarily for the State of California) are made on glass bead content in paint, paint thickness, physical properties of pavement, marking equipment, installation methods, and equipment and methods for improving installation and maintenance. Total annual savings for the California State Highway System, which would result from implementing all recommendations, were estimated to be $800,000 out of a total delineation budget of $5,107,000 for FY'74 - '75.

Another similar report issued by the FHWA is "An Overview of Roadway Delineation Research", authored by D.G. Capelle (FHWA-120-78-111). This report provides an overview of recent FHWA research on the subject of improving the effectiveness of roadway delineation. It summarizes six recent major studies, synthesizes their findings, identifies gaps, and provides information and advice which can be used for implementation planning.

The paragraphs which follow are a broad summary, generally from the literature described above, augmented by current information obtained from manufacturers and users of highway guidance equipment.

6-2 PAVEMENT MARKING PAINTS AND MATERIALS

Pavement marking paints are classified according to type of base: alkyd, rubber vinyl, epoxy, water, and high polymer. The wear of these paints depends on the type of surface, climate, and traffic.

Reflectorized paint is made by mixing glass beads with conventional paints. A typical cost for paint is $0.022 per foot ($0.072 per meter). Cold-applied plastic is usually reserved for crosswalks and messages. The lifetime is three to four years. Beaded plastics are used for enhanced visibility. Thermo-plastics are better for high traffic volume but are 15 times more expensive to install than conventional paint. The average cost is $0.33 per foot ($1.08 per meter). Figure 23[1], taken from Roadway Delineation Systems[2] provides guidelines for deciding whether a particular striping application should be implemented with paint or thermoplastic material. Table 7[1], from the same source, gives an idea of typical annual paint striping costs.

Three tables from State-of-the-Art on Roadway Delineation Systems [3] are included to show typical costs and life expectancies. Figure 24[4] shows the typical relationship between life expectancy and traffic volume for beaded paint on different surfaces. Table 8[5] is a table of cost-effectiveness factors for paint and plastic road markings for Washington, D.C., while Table 9[4] shows costs per foot for paints and thermoplastics. Table 10[6] shows comparative costs for painted lines, grooved lines, and raised markers. Table 11[4] is a summary of costs and life expectancy for highway markers suitable for surface application.

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[1]Source: Chaiken, B., Comparison of the Performance and Economy of Hot-Extruded Thermoplastic Highway Striping Materials and Conventional Paint Striping, Pub. Roads, Vol. 35, No. 6, Feb. 1969, p 149.

[2]Pennsylvania State University and Institute for Research, prepared for Highway Research Board, NCHRP Report No. 130, 1972.

[3]Bali, S.G./McGee, H. W.; Taylor, J.I.; Science Applications, Incorporated; sponsored by: Office of Research and Development, FHWA-RD-76-73, Final Report, May 1976

[4]Lanz and Davis, 1973

[5]Flanakin, 1975

[6]Shelly, Rooney, and Chatto, 1972

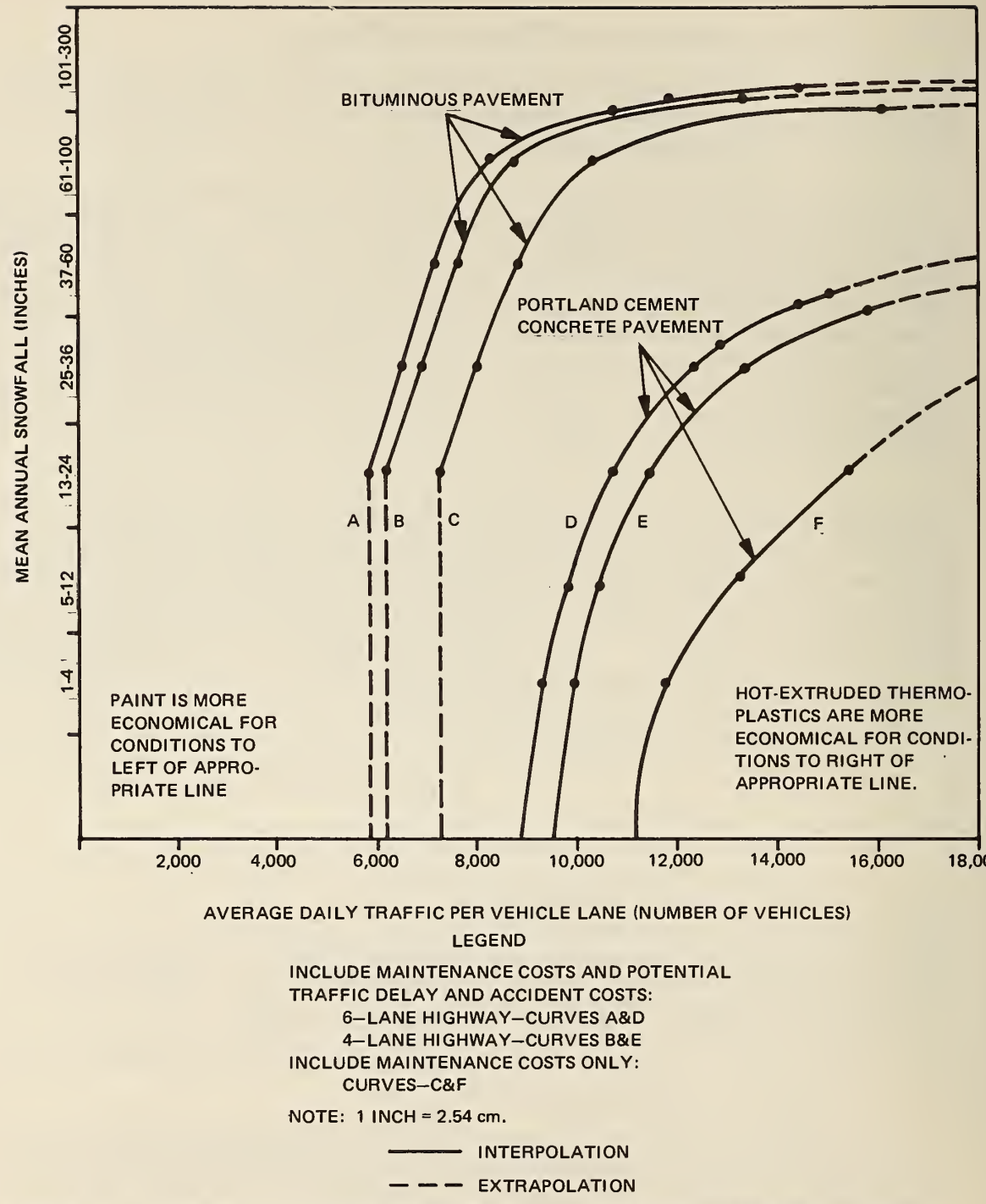


Figure 23. Guide for Selecting the Most Economical Striping Material: Paint vs. Thermoplastic

TABLE 7. ANNUAL COST OF CONVENTIONAL PAINT STRIPING[1]

Item[2]	Average Daily Traffic (ADT) per Lane (Number of Vehicles)															
	1,000	2,000	3,000	4,000	5,000	6,000	7,000	8,000	9,000	10,000	11,000	12,000	13,000	14,000	15,000	16,000
Useful paint life (years)	1.32	1.02	0.87	0.75	0.67	0.60	0.55	0.50	0.45	0.42	0.38	0.36	0.35	0.33	0.32	0.31
Annual striping frequency [3]	.76	.98	1.15	1.33	1.47	1.67	1.82	2.00	2.22	2.38	2.63	2.78	2.86	3.03	3.12	3.22
Annual basic paint striping cost, per linear ft. per year (A) [4] (cents)	1.67	2.16	2.53	2.93	3.28	3.67	4.00	4.40	4.88	5.24	5.79	6.12	6.29	6.67	6.86	7.08
Annual costs of paint striping on 4-lane divided highway:																
Cost of traffic delay, per linear ft. per year (8)[5] (cents)	.02	.05	.11	.16	.23	.31	.39	.49	.61	.73	.89	1.02	1.14	1.30	1.43	1.58
Cost of potential traffic accidents, per linear ft. per year (C)[6] (cents)	.00	.01	.01	.02	.03	.04	.05	.06	.08	.10	.12	.13	.15	.17	.19	.21
Total annual cost, per linear ft. per year (A)+(B)+(C)(cents)	1.69	2.22	2.65	3.11	3.54	4.02	4.44	4.95	5.57	6.07	6.80	7.27	7.58	8.14	8.48	8.87
Annual costs of paint striping on 6-lane divided highway:																
Cost of traffic delay, per linear ft. per year (D)[5] (cents)	.03	.07	.16	.25	.34	.46	.59	.74	.92	1.10	1.33	1.54	1.71	1.96	2.16	2.39
Cost of potential accidents, per linear ft. per year (E)[6] (cents)	.00	.01	.02	.03	.04	.06	.08	.10	.12	.14	.17	.20	.22	.25	.28	.31
Total annual cost, per linear ft. per year (A)+(D)+(E)(cents)	1.70	2.24	2.71	3.21	3.66	4.19	4.67	5.24	5.92	6.48	7.29	7.86	8.22	8.88	9.30	9.76

Notes

[1] Costs given separately and collectively for basic installation, traffic delay, and potential accidents

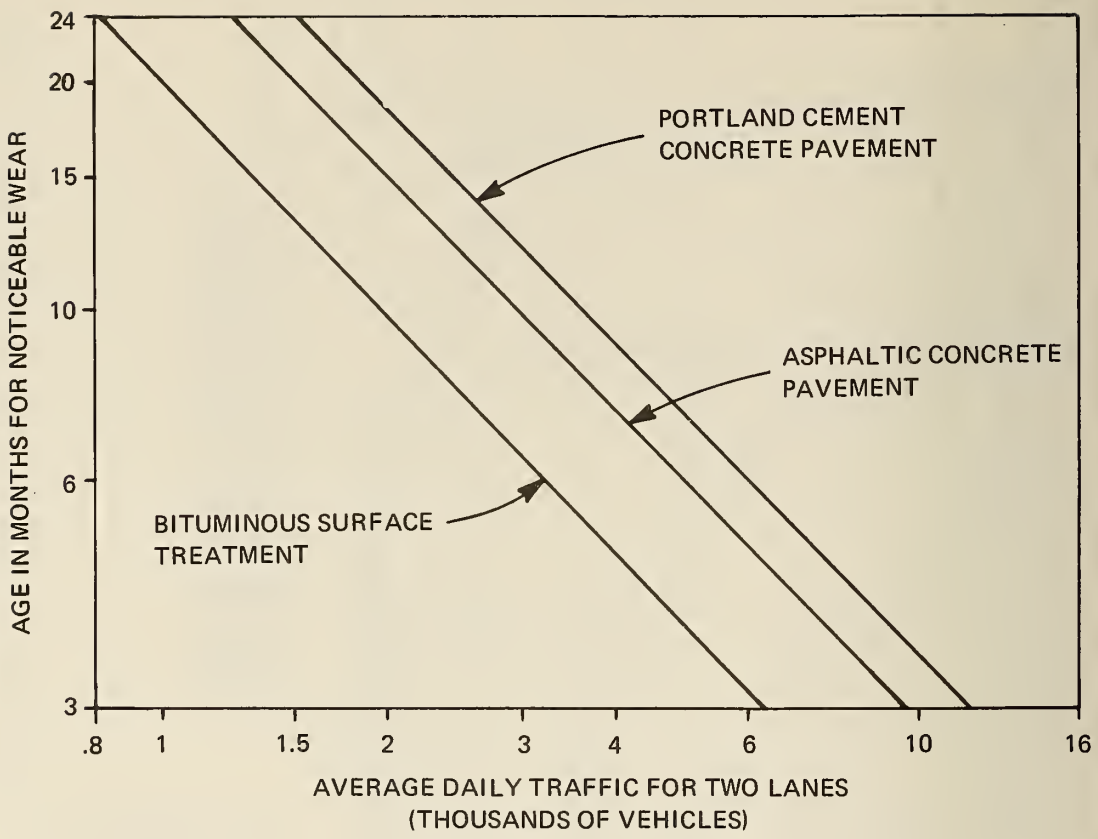
[2] One foot = 0.3048 meter; 1 inch = 2.54 cm

[3] Calculated from data on *useful paint life.*

[4] Basic materials, labor, and installation costs calculated from: annual striping frequency X 2.2¢ (average cost per linear foot of 4-inch stripe per installation).

[5] Calculated from: 7.65×10^{-6} X total ADT X annual striping frequency.

[6] Calculated from: Total ADT X 10^{-6} X annual striping frequency.



NOTES
ROAD WIDTH: 24 FEET (7.3 METERS)
PAINT THICKNESS: 15 MILS (0.381 MILLIMETERS)
BEAD AMOUNT: 6 POUNDS/GALLON (0.72 KILOGRAMS/LITER)

Figure 24. Conditions for Noticeable Traffic Stripe Wear

TABLE 8. PAVEMENT MARKING COSTS, SERVICE LIFE, AND COST EFFECTIVENESS OF MATERIALS USED IN WASHINGTON, DC

Markings and Properties	Conventional Paint (Cents)	Instant Set (Cents)	Thermoplastic (Cents)	
			By D.C. Forces	By Contractor
Crosswalks and Stop Lines				
Cost per Linear Foot	8	12	32	43
Service Life	1.7	2.6	20.0	20.0
Cost Effectiveness	4.8	4.8	1.6	2.1
Lane and Center Lines				
Cost per Linear Foot	1.8	1.9	19	26
Service Life	1.7	2.6	20.0	20.0
Cost Effectiveness	1.06	0.7	0.95	1.30

Notes

- Service Life is a measure of the number of vehicles per line that have passed over the material when the marking is no longer serviceable due to loss of luster or reflectivity (night visibility), or having been worn completely from the surface in the wheel paths.
- Cost Effectiveness is the ratio of the cost per linear foot of marking to the service life, expressed in millions of vehicles per lane of traffic.
- All costs reflect 1975 prices.
- 4.1 feet = 0.3048 meter.

TABLE 9. SOME COSTS OF CONTRACT MARKING, CALENDAR YEAR 1971

State	Material	Color	Quantity		Cost	
			(Feet)	(Meter)	($/Foot)	($/Meter)
New Jersey	Traffic Paint	White	17,557,414	5,351,500	0.013	0.043
		Yellow	1,337,583	407,695	0.013	0.043
Oklahoma	Thermoplastic	White	225,000	68,580	0.015	1.033
		Yellow	17,000	5,182	0.285	0.935
S. Carolina	Thermoplastic[1]	White	502,134	153,050	0.130	0.427
District of Columbia	Thermoplastic	White	96,362	29,371	0.566	1.857
Illinois	Thermoplastic	White	908,626	276,949	0.350	1.148
		Yellow	122,700	37,399	0.350	1.148
Florida[2]	Thermoplastic	White	1,792,481	546,348	0.140	0.459
Arizona	Thermoplastic	White	595,000	181,356	0.120	0.394

Notes

[1] Sprayed

[2] Combination of contractor-supplied equipment and state forces

TABLE 10. COMPARATIVE COSTS OF PAINTED LINE, GROOVED LINE, AND RAISED MARKERS

Item	Initial Cost ($/Mile)[1]	20 Year Cost ($/Mile)[1]	Cost Per Year ($/Mile)[1]
Plain Painted Line	120[2]	1070	53[3]
Grooved Line	720	1670	83[3,4]
Raised Markers	950	1900	95[4]

Notes

[1] One mile = 1.609 km.

[2] Cost of initial striping includes alignment and two coats of paint.

[3] Costs based on one restriping per year.

[4] The life of a grooved stripe is estimated at 20 years. The life of the raised marker system is estimated at 10 years.

TABLE 11. SUMMARY OF MATERIALS STUDIED

Item	Traffic Paint 15 Mils 2/6#/gal.	Thermoplastic 75-130 Mils with Dressing Beads	Raised Nonreflective Markers Ceramic	Raised Reflective Markers Plastic
Equipment Cost	Min. - $1,000 manual. Production - $35,000 (auto.)	Min. - $8,000 hand. Production - $25,000 (auto.)	Min. - $5,000 estimate Production - Estimate $20,000-$50,000 (auto.)	
Type Application	Atomizing Spray (60 psi) or Airless Spray (1,500 psi)	Extrusion (Screened) or Atomizing Spray (60 psi)	Two component epoxy with manual placement. (sand blast required on Portland Cement Concrete Pavement)	
Service Life	Avg. - 1 year Min. - 4 months Max. - 2 years	Avg. - more than 10 years Min. - 5-7 years Max. - not known	Service life not known for our conditions	
Cost (estimate) (skip-line per mile)	$65 State Forces $120 Contract	$300-500 State Forces $500-560 Contract	$640 Contract	$220 Contract
Effectiveness	Day: Good-Excellent Night Wet: Very Poor Dry: Good-Excellent	Day: Good-Excellent Night Wet: Poor Dry: Good-Excellent	Night: Poor (non-reflective) Day: Good (non-reflective)	Day: Poor Night Wet: Excellent (Reflective) Dry: Excellent (Reflective)
Cost/mile for 10 years; no interest included	Avg. - $700 Annual Min. - $335 Biannual Max. - $1235 Semi-Annual Average cost of edge stripe $335	Avg. - $550 Min. - $500 Max. - $1,200 Average cost for 125 mil edge line $1,335	Avg. 2-7 percent lost per year Max. 5-10 percent lost per year Use limited to maximum conditions at present; Estimate avg. cost $1,100	Avg. 1-3 percent lost per year Max. 2-6 percent lost per year Use limited to maximum conditions at present; Estimate avg. cost $400

Notes
1 Mil = .00254 cm
1 MILE = 1.609 km

6-3 POST DELINEATORS

Post delineators are made of a plastic or metal post with one or more reflectors and are used as edge markers. They are particularly effective in northern climates where snow accumulation is great. They have a long life expectancy when kept clean and not plowed or knocked over. In California, however, post delineators do not have a long life. Out of 650,000 post delineators installed on state highways, 350,000 have to be replaced annually due to knockdowns or vandalism. Initial cost is typically $74 to $145 per mile ($46.0 to $90.10 per kilometer) depending on spacing and the type and number of reflectors. They are best for poor visibility but still marginal as guidance cues in fog or other reduced visibility condition. Road dirt reduces the effectiveness significantly. They are of little value in daytime and on roads with high natural or artificial illumination levels.

6-4 RAISED PAVEMENT MARKERS

Raised pavement markers are available in reflective and nonreflective varieties, ranging from ceramic daytime markings to snowplowable retro-reflectors in steel housings. They can be very effective under poor visibility conditions depending on road conditions, but are useless when covered by snow. The initial cost is very high and maintenance can be high in areas subject to high levels of dirt accumulation. A typical cost of standard ceramic markers (assuming the markers are installed in a pattern of four markers at three foot intervals, followed by a 15 foot gap and a single retro-reflective marker in every other gap) is $950 per mile of lane ($590 per kilometer of lane), or 10 to 15 times more expensive than a painted line. Life expectancy varies from 1.5 to 10 years depending on climate and traffic.

6-5 CURRENT SURVEY RESULTS

Twenty-five manufacturers and state agencies were contacted in the survey of roadway delineation equipment. Of these, 15 responded with information, which are summarized below.

a. POST DELINEATORS

1. Hawkins-Hawkins Co., Inc., 1255 E. Shore Highway at Gilman, Berkeley, CA

This company supplies post delineators according to various state specifications on competitive bid. Typical prices are $15.40 for a fluorescent red post with a reflective bead band. The post is epoxied to the pavement. Epoxy costs $22 per gallon ($5.82 per liter). A rubber post without the band costs $9.30 and $1.50 reflectorized (min. quantity of 50). No operating costs are available.

2. Lanco Industries of Columbus, P.O. Box 20229, Columbus, OH 45220

This company supplies delineator supports made of flexible polymer plastic. Prices vary according to state specification and bidding factors. Typical prices are $12 for model LDP6 which is four feet (1.2 m) long, four inch (10.2 cm) wide on the face, and $6 for model LDP8 which is three inch (7.6 cm) wide on the face and made of extruded material. The manufacturer estimates a 30 percent per year loss factor.

3. Proven Products, 7560 SW Lakeview Drive, Portland, OR 97219

PP imports a delineator post made in Austria. It is distributed by Syro Steel Co., Girard, Ohio. It is made of polyethylene and stated to last longer than steel. It will hold a Stimsonite reflector or 3M high intensity tape. The posts cost $10.50 in quantities of 10 to 99, $9.50 for 100 to 499, and $9.25 for 500 to 999, and $9.00 for 1,000 and up; all prices fob Ohio. A three by five inch (7.6 cm by 12.7 cm) patch of reflectorized 3M tape costs $1.25 as does the Stimsonite acrylic reflector. No operating costs were given.

4. Transpacific Equipment Corp., 1901 Ave. of the Stars, Los Angeles, CA 90067

This company once manufactured an all plastic TecPost delineator. This was discontinued and replaced by metal delineator posts costing $12 for a 60 inch (152 cm) post with a six inch (15.2 cm) reflector, and $10 for a 30 inch (76 cm) post with a six by three inch (15.2 cm by 7.6 cm) reflector. Prices vary according to state specifications and competitive bidding.

5. Zumar Industries, Inc., 2828 Stanford Ave., LA, CA

Zumar manufactures according to state specification and gave the following prices according to California specifications: six foot (1.8 m) post made of 11 gage steel (2 lb. per ft. (2.98 kg per meter)) in quantities of 100 or more, $5.55 with an 8 by 24 inch (20.3 cm x 61.0 cm) plate, $5.95 with 1 reflector, $6.35 with 2 reflectors, and $6.70 with 3. A six foot (1.8 m) post with a 3.5 by 12 inch (8.9 cm by 30.5 cm) plate is $5.10, $5.45 with 1 reflector, and $5.85 with 2. Prices vary according to state.

In discussions with some state officials, the following was learned.

The State of Washington uses a Stimsonite delineator costing 24¢ mounted on a three by nine inch (7.6 cm by 22.5 cm) backplate costing 26¢ and a post of channel steel 4.5 feet (1.37 m) long costing $2.54. The completed installation including labor costs is $11.52.

Michigan uses a seven foot (2.1 m) post costing $3.16 with round amber and red reflectors. The last bid price was 45¢ per foot ($1.48 per meter) for the posts and $0.25 apiece for the reflectors.

The New Jersey DOT uses 3 types of delineators, all being aluminum U posts with a hold to mount one, two or three reflectors. The 1975 bid prices were $11.28, $11.97 and $15.00 for each.

The Ohio Turnpike uses Stratolite No. 75 reflectors costing 20 cents each mounted on a six foot (1.83 m) (1.12 lb per foot (1.67 kg per meter)) post at 264 feet (80.5 m) intervals. The posts cost $2.10 in lots of 1,500. The reflectors are replaced at a rate of 10,000 per year due to loss by various means. Maintenance costs (replacement) are about $9K per year.

b. DELINEATORS FOR ROAD AND POST MOUNTING

1. Amerace Corp., Signal Products Div., 7542 N. Natchez Ave., Niles, Illinois

Amerace is the manufacturer of the popular Stimsonite line which includes many styles and types of post mountable and roadway implant reflectors. Prices range from 40 cents to $4.95 each in quantity; for example, $1.20 for one-color bi-directional reflector in quantities of one to ninety-nine; $1.60 each for two-color bidirectional reflector in same quantity; and $4.95 for snow-plowable in-pavement reflective roadway delineator. No operating costs are available from manufacturer as too many factors affect life.

2. Cataphote Div., Ferro Corp., P.O. Box 2369, Jackson, Mississippi

Ferro manufactures reflective and nonreflective ceramic road delineation buttons that are normally cemented to the road surface. In quantities of 5,000, the cost is 30 cents each for nonreflective, 65 cents each for one-way reflectors, and 90 cents each for two-way reflectors. Epoxy costs about ten cents per marker. The manufacturers estimate a two percent per year loss factor.

3. 3M, Safety Systems Div., 3M Center, Bldg. 223-3N, Dept. 45, St. Paul, Minnesota

Reflective sheeting is available in bulk for fabrication of delineators at about $1.80 per square foot ($19.27 per square meter) depending on quantity. Fabricated delineators for post mounting are sold at bulk rates of 50 cents to $1.00. Maintenance involves occasional cleaning, one to four times per year depending on climate.

6-6 LIGHT SOURCE GUIDANCE DEVICES

a. PAVEMENT INSET LIGHTS

Guidance aids have been found to be more effective for both day and night use. When installed as lane delineators, the lights serve two functions. They provide an alternate source of visual cues which help orient the driver, normally provided by the edge of the road and the painted lane delineators. Second, they provide some indication of relative density of fog ahead. For best results, the intensity of the lights should be made variable and adjustable as a function of ambient

light level and fog density. This aids in reducing glare and dazzle at night, particularly in thin fog, and helps reduce the possibility of a grossly misleading apparent visibility while still providing help under daylight conditions.

There is some question as to whether improved roadway delineation is in fact desirable under conditions of significantly reduced visibility. Improved delineation can produce an increase in speed variation under such conditions. The better roadway outline may provide a false sense of security, and thus might induce some motorists to overdrive their safe stopping distance. This coupled with the fact that other motorists may continue to drive more cautiously, can increase the accident potential.

The above problem has stimulated interest in other devices which can provide headway (occupancy) information. One delineator providing both longitudinal and headway (occupancy) information is a pavement inset light located at the center of the driving lane. The presence of a lead vehicle is indicated to the following vehicle by the blocking of the lights. Vehicle speed can then be adjusted based on the number of visible lights. There is a serious disadvantage to this system since motorists are conditioned to driving between delineators, not straddling them. One possible way to overcome this problem is to use inset lights (at the center of the lane) in conjunction with lighted lane delineators. The former could be of a different color and not as bright as the lane delineators. Another refinement would be to progressively energize the inset lights at the recommended driving speed, forming in effect, a pacer system. In this way, vehicles not maintaining speed synchronization with the lights would lose the guidance aid. Such installations are, of course, complex and quite costly. Furthermore, motorists would have to be educated for this novel approach. Its application would be limited to localized recurrent visibility problems on small sections of roadway.

A few manufacturers produce inset lights which are mainly used on airport runways. Connecticut International, Sepco Division (Windsor Locks, Conn.) provides the majority of runway lights to the FAA. They have provided lights for highway and bridge delineation systems. Their inset light L850A is a six amp filament lamp requiring a separate regulator providing constant current. The cost is about $375 per unit for the 200 watt unit. A 70 kw regulator with 20 amp output costs $11,800 while a 10 kw regulator costs $6650. Lamps used by Virginia at Afton Mt. cost $150 each for 845 units. The manufacturer's representative declined to give specific operating costs, saying this depends greatly on the specific installation.

b. STROBE LIGHTS

Another guidance aid which provides improved guidance information during low visibility conditions is the strobe light. This high intensity light can be mounted in the median or edge of the road, and when fog is detected, flashed sequentially in the direction of vehicle motion. Strobe lights can be made brighter than other illuminating devices because of their short duration, and can, therefore, be seen and illuminate objects at greater distances.

Strobe lights are apparently an effective guidance technique; however, their application is geared primarily toward use on a small section of roadway having a well-defined and repetitive visibility problem. Spacing of strobe lights is between 50 to 100 feet; thus, costs mount rapidly as the length of section increases. Sequential timing also becomes more of a problem for extended sections.

Strobe light guidance systems formerly manufactured by Elco and Strong are no longer available. Because of low demand, the Strong Electric Corporation ceased manufacture, and the Safecraft Division of Elco is out of business. A few manufacturers still produce so-called "pancake" lights suitable for inset applications.

Section 7

COMMUNICATION AND RADIO AID EQUIPMENT SURVEY

7-1 INTRODUCTION

The following survey attempts to relate the vast field of communication alternatives and equipment to reduced visibility applications. Because equipment and costs vary so widely depending on what is to be transmitted, the survey is presented in two parts. Paragraph 7-2 discusses data communications techniques and equipments. Paragraph 7-3 discusses voice communications and equipment.

In the paragraph on Data Communications, the discussion is referenced to a "typical" reduced visibility system data source so that equipment and techniques can be compared relative to the same baseline. The "typical" location consists of:

- Four vehicle detectors
- One visibility or fog detector
- One variable message sign.

7-2 DATA COMMUNICATIONS

a. DATA REQUIREMENTS

The data requirements are determined by the number of bits to be monitored and the frequency of monitoring, or sampling rate. The sampling rate is a function of the maximum frequency of variation of each bit and the resolution necessary for efficient operation of the system - the greater the required resolution, the higher the required sampling rate.

The following example serves to illustrate how one would define the system requirements for the typical reduced visibility site. Table 12 shows the number of data points that have to be monitored or controlled for each device, the sampling rate and the data transfer required for the system. Note the system data rate is governed by the detectors, which require a high resolution to calculate speed, occupancy, and volume.

b. COMMUNICATION MEDIUM

The medium which carries the data between central and the remote sign is generally one of three kinds: leased lines (telephone), owned cable (direct cable), or radio. The characteristics of each are summarized in Table 13.

TABLE 12. DATA REQUIREMENTS FOR A TYPICAL RVG SYSTEM LOCATION

Equipment Type	Quantity of Equipment	Samples per Second (A)	Number of Data Points (Bits) (B)	Data Transfer Rate (Bits per Second) (A x B)
Vehicle Detector	4	30*	4**	120
Visibility Sensor	1	1/60	6	1/10
Variable Message (Command)	1	1/60	6	1/10
Variable Messages (Monitor)	1	1/60	6	1/10
System Totals			22	120

NOTES:

*This sample rate is based on a 0.50 MPH (0.805 KM/HR) speed resolution. If five MPH (8.05 KM/HR) resolution is sufficiently good, the required sample rate can be reduced to three per second.

**One bit from each of four detectors

TABLE 13. TRANSMISSION MEDIUM

Medium	Distance	Applicable Characteristics Modulation			Comments
		DC	FDM	TDM	
Leased Line	Limited mainly by cost	•	•	•	Leasing costs unpredictable. Subject to service interruptions
Owned Line	12 miles without repeaters	•	•	•	High initial costs Negligible operating costs Excellent reliability
UHF and UHF Radio	Line of sight distance limited by transmitter height and power				Requires FCC licensing — lengthy complicated process 450 MHz (P-Band) — congested, few available channels — limited to non-urbanized areas
			•	•	960 MHz (L-Band) — availability of channels greater than 450 MHz
					Subject to fading and atmosphere phenomena common to less reliable radio systems. More difficult to maintain than wire systems. Capacity up to six voice grade channels. Each channel (2400 Hz) equivalent to one cable pair.

Note
1 Mile = 1.609 km

Leased lines utilize the telephone network as the transmission medium. Voice grade lines, leased from the telephone company, are connected between the remote site and central. The distances involved can be virtually unlimited in that the reduced visibility communications are treated as a telephone communication. The cost incurred in burying cable is not present in a leased line system. The disadvantages of this system include: escalating telephone costs (the costs depend upon the local tariff), interruptions common to local telephone service, and dependence upon the telephone company for maintenance. The cost is, of course, dependent upon the number of pairs required; the number of pairs being a function of the modulation technique selected.

Owned cable systems provide a direct connection between central and the field. The cables, of voice grade quality, are buried either along the side of the road or in the median strip, or hung from utility poles. The cable consists of several shielded twisted pairs in a jacket sheath. While this system has a high initial cost, dependent upon such factors as number of pairs required to transmit the data, distance and terrain, it requires virtually no maintenance. It is advisable, however, for the user to provide spare capacity in his cable plan to allow for future expansion and provide for replacement pairs in case of damage or growth, eliminating the need for costly trenching at a later date.

Radio systems utilize the airway as the transmission medium, eliminating the need to route cable to the remote site. Radio systems are thus very attractive where the remote location of the site, its geography, or the distance from central preclude the use of a cable system. Radio systems can operate independently of conventional power lines by utilizing solar cells and batteries or other locally generated power. The solar cells and batteries can also be used to power modulation equipment and visibility detector.

In the United States, all radio transmission is under the aegis of the Federal Communication Commission (FCC). All radio systems have to be licensed by the FCC, and the user agency has to abide by its rules and regulations. The radio systems used in the reduced visibility application would be governed under the Public Safety Radio Services - Parts 89 and 94 of the FCC Rules and Regulations. These regulations define the frequencies available for use, the maximum antenna height, and radiated power. While several frequency bands, including 39 MHz and the band from 453 to 470 MHz, are available for use, they are not considered for this application due to their high congestion and, in some cases, susceptibility to atmospheric perturbations resulting in interference by distant stations operating on the same frequencies. The recently authorized 960 MHz band is probably the best band for the reduced visibility system application. This band is in the microwave frequency range, and therefore is directional line of sight. Obstructions, such as mountains or tall buildings in the transmission path, would necessitate the use of repeaters - increasing system cost. Locating the antenna on a high object can eliminate or reduce the need for repeaters.

There are cases in which a combination of radio and cable is advantageous; for example, a system in which there are several data sources in fairly close proximity to each other but distant from the central location. Since one radio station can accommodate several sites, a tradeoff may show that cable connecting the sites to a properly placed transmitter is better than separate transmitters at each site.

While a microwave system does, in certain applications, have several advantages over a cable system (e.g., when sites are remote), it is more complex; hence, less reliable and more expensive to operate and maintain; and is more subject, especially the antenna, to vandalism. Microwave systems are also subject to fading and noise induced by atmospheric disturbances. The FCC licensing procedure can also be lengthy and time consuming.

If a decision is made to use a radio system, the vendor should be selected as soon as possible in the implementation schedule. The FCC, as part of its licensing procedure, requires data to be submitted on terrain, antenna characteristics and transmitting power. The manufacturers have the expertise and resources to provide this data and assist in filing the required documents with the FCC.

c. TRANSMISSION AND MODULATION TECHNIQUES

The selection of the means of modulating the data for transmission should be made in conjunction with the selection of the medium. Three basic modulation techniques exist. These are Direct Wired dc (DC), Frequency Division Multiplexing (FDM), and Time Division Multiplexing (TDM).

1. DC

DC utilizes a dedicated cable pair for each bit of information transmitted. Relays, either mechanical or solid state, are incorporated in the field equipment and connected to a corresponding relay or switch at central. When a bit is active, a contact closure results. This closure is detected by the receiving relay initiating the appropriate action. The relays are usually designed into the initiating or reacting pieces of hardware, eliminating the need for separate communication modules. This is a very simple system and is easy to maintain. It is inefficient in that a cable pair is required for each bit of information. Figure 25 is a block diagram of a typical DC system.

Various modified versions of this scheme can reduce the number of cable pairs required. They reduce, however, the maximum transmission distance. DC techniques are suitable for use over owned lines and some types of leased systems.

Our typical site (see Figure 25) would require 22 cable pairs in a DC system.

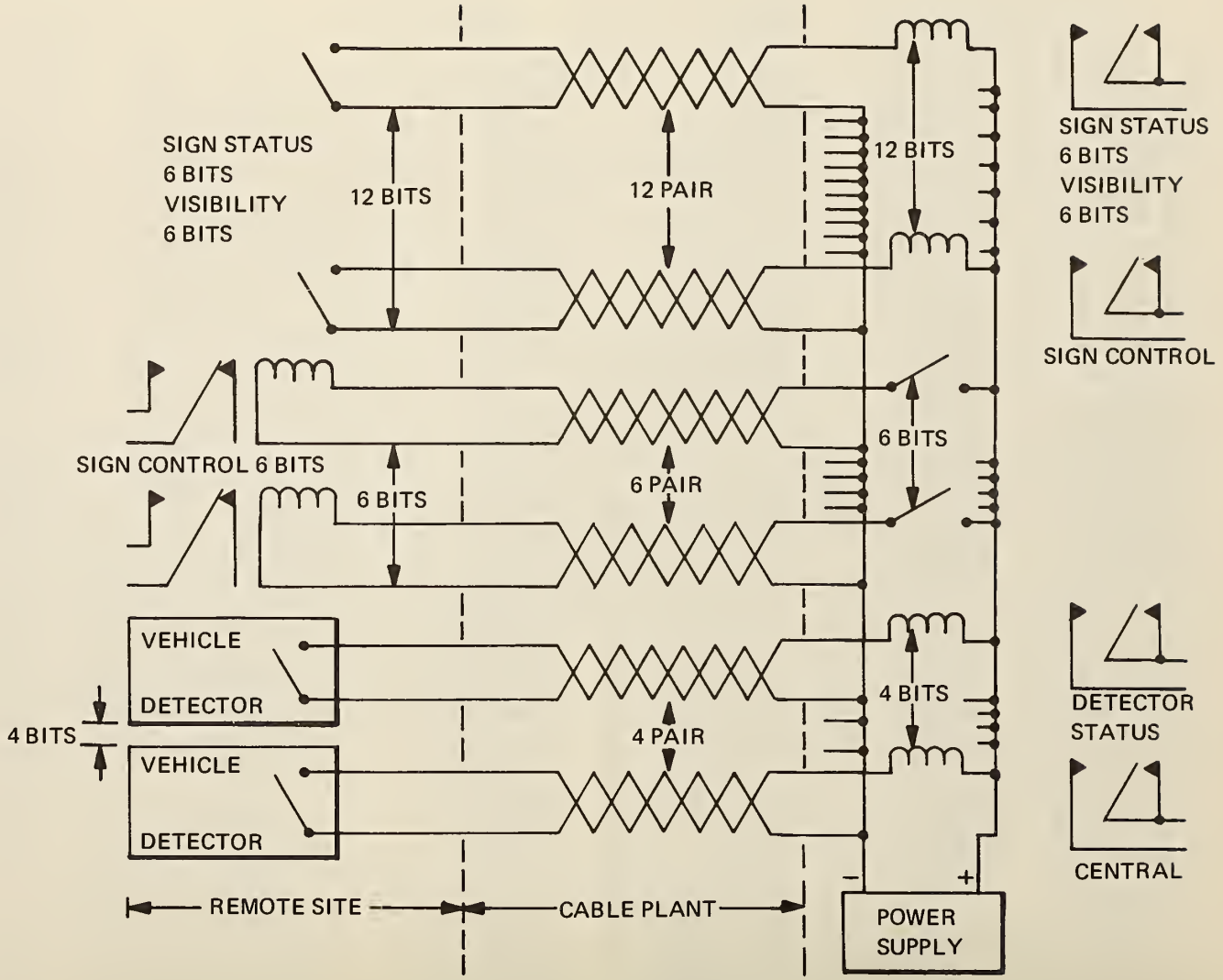


Figure 25. DC Communication

2. FDM

In this technique, the bandwidth of the transmission medium is partitioned into channels. A transmitter-receiver set of the same frequency (tone) is assigned to each channel. The data from each data point is transmitted over a separate channel.

The voice grade cable used in an owned or leased line system has a bandwidth of 3,000 Hz that is normally divided into 18 channels spaced 120 Hz apart. The minimum spacing is a function of data rate and the characteristics of the transmission link. Guard or isolation bands are provided to prevent overlapping of data and the frequencies below 420 Hz and above 2,500 Hz are normally unassigned due to the bandpass characteristics of the lines. The maximum transmission distance without amplification and reshaping is a function of the frequency of the highest channel. With 18 channels, the distance is about 12 miles (19.3 km); if fewer channels are used, this distance would be increased.

Two methods of modulation are commonly used in FDM: amplitude modulation (AM) and frequency shift keying (FSK). In AM, the tone is keyed on and off by closure of a pair of contacts or dc voltage. In FSK, the tone's frequency is shifted by the keying signal, the keying being initiated by the presence of a data bit. While the cost of an AM system is less than for an FSK system, it has poorer noise immunity - this is very important in transmission over media subject to noise or fading, such as microwave links or poor quality transmission lines.

FDM equipment is compatible with leased line, owned cable, or radio transmission media.

Figure 26 is a block diagram of an FDM system for the "typical" reduced visibility site. Twelve channels would be required to transmit the sign and visibility status from the field, six channels to carry sign commands, and four channels to transmit vehicle detector data. In a wire system, these 32 channels would require one cable pair and four channels on a second cable pair. The unused capacity of the second pair would be available to carry tones from another site.

3. TDM

TDM involves the periodic sampling and multiplexing of several data points onto a single transmission pair. Synchronization must be provided between the transmitter and receiver. Among the synchronization methods available are sequential scanning and polling.

In sequencing scanning, the data points are scanned in sequence with synchronization and framing bits used to identify the start and end of the data sequence. This sequence can then be transmitted over a tone channel using FDM techniques.

The capacity of each channel is dependent upon the manufacturer's design (typically eight to eleven bits/channel) and the data rate. Some designs utilize an additional bit called a Parity Bit. This bit is used to detect errors occurring in the communication process. For the typical site (see Figure 27), the sign and visibility detector status would be multiplexed one tone channel, the sign control commands would be multiplexed onto a second tone channel and each of the detectors, due to

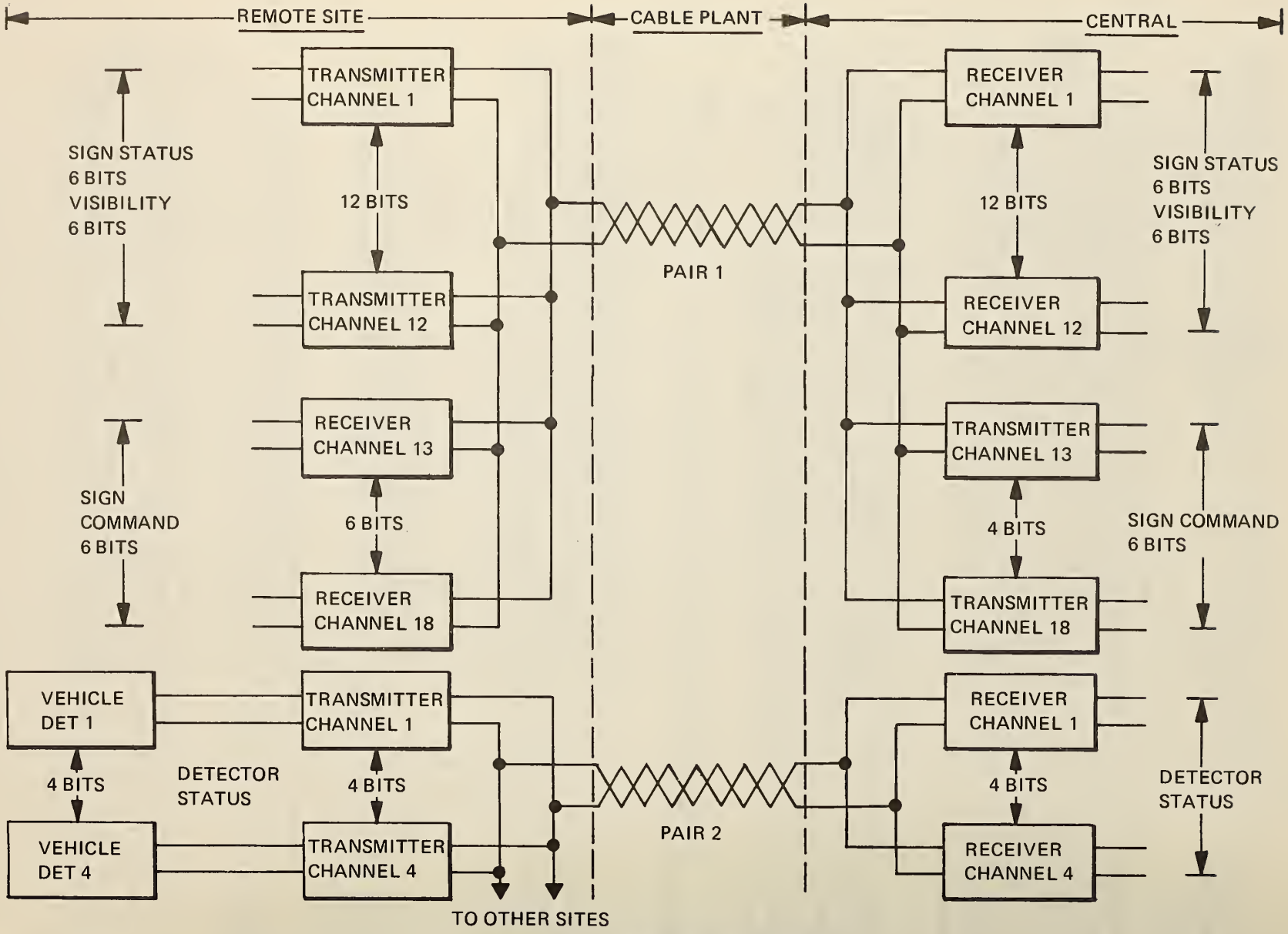


Figure 26. FDM Communication

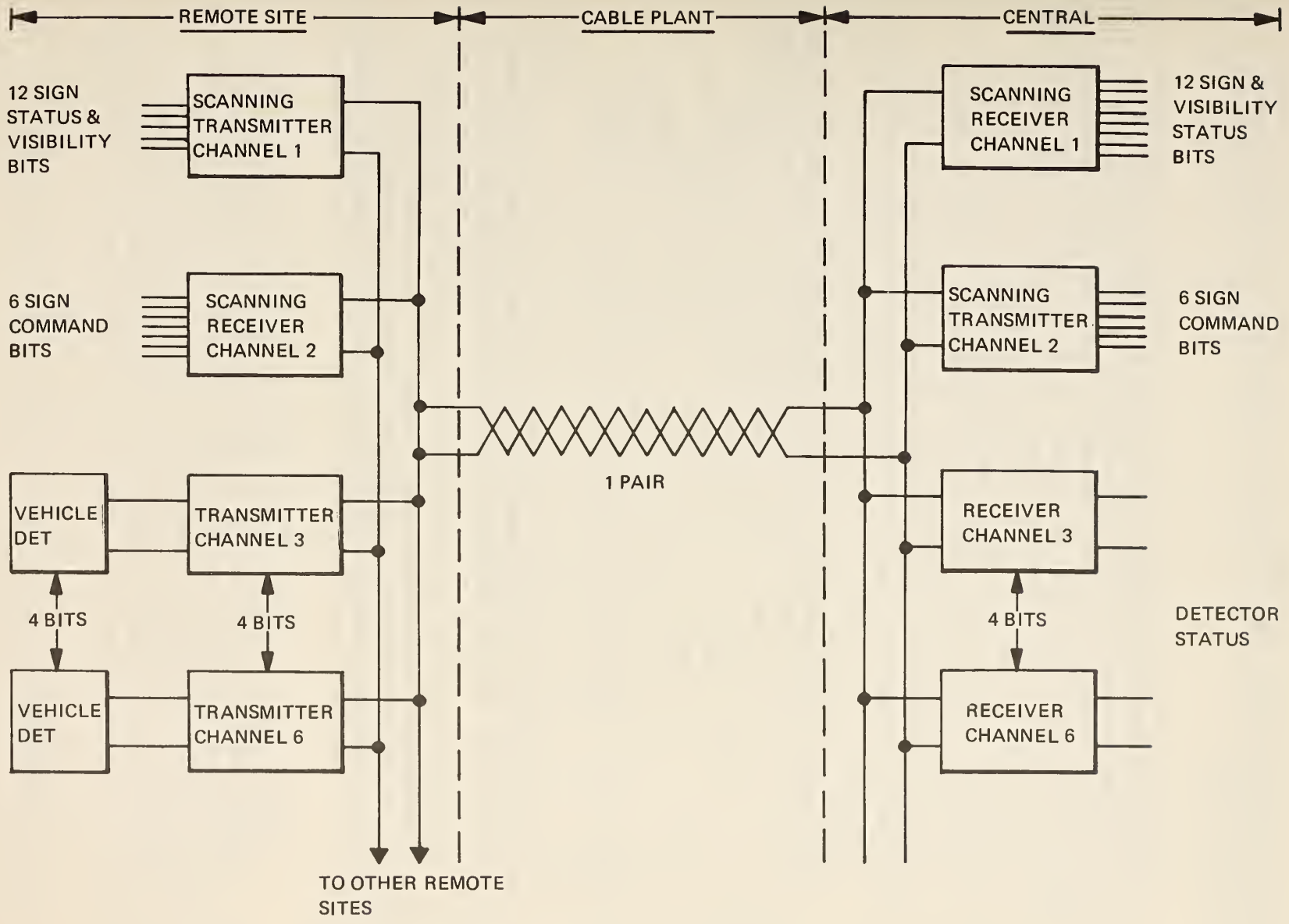


Figure 27. TDM–Scanner Communications

its high data rate, would use a separate channel. Thus, six channels could handle the data requirements that required 22 ordinary FDM channels. The concomitant cost savings must be traded off against the increased complexity of the equipment and troubleshooting.

Polled (supervisory control) systems are used whenever a large number of remote sites have to be interrogated and/or controlled. Up to 63 sites can be controlled over one cable pair. Each remote site is assigned an address. All messages transmitted from central are prefaced by a synchronizing sequence and the address of the remote unit being interrogated. A remote unit will respond only if it has been addressed. The messages transmitted from central can either be control or interrogation commands. The remote unit addressed will preface its response to central with a synchronizing sequence followed by its own address and data. The message security (error detection capability) can be made very high through the use of sophisticated coding techniques, the inclusion of parity, and/or message repetition. These, of course, reduce the efficiency of the system because they reduce the percentage of bits containing information. For instance, a typical 32 bit message might contain only eight data bits - a 25 percent efficiency.

The standard communications cable pair has a maximum capacity of 1,200 bits per second. If a 32 bit length message is assumed for each command and each response word, then approximately 16 interrogations can be made per second. This limit does not present a problem for the sign and visibility sensor monitor and control function; it does, however, fail to fulfill the vehicle sensor requirement of 120 interrogations per second (30 for each detector). This problem can be circumvented by either installing remote processing equipment in the field which preprocesses the data into a more compact form for transmittal, or by using different communication techniques for the sign and visibility detector, and vehicle detectors.

The installation of pre-processing equipment at each remote site eliminates the need to interrogate the four vehicle detectors 30 times per second each to obtain adequate resolution for speed and occupancy computation by the central computer. The remote processor, which can be a microprocessor, calculates the average speed, volume and average occupancy from the raw data over a period of several minutes, and stores and encodes that data into a word suitable for transmission when commanded by the master at central. An alternative is to use the supervisory control system only for the low data rate sign monitoring and control and visibility detector monitoring. An FDM type system would be utilized to transmit the vehicle detector status.

TDM equipment also requires less space than corresponding FDM equipment. In FDM a separate module in central and in the field is required for each data point. A polled TDM system generally only requires one rack-mounted module at central for each transmission pair and only one module at each remote site. Where space is limited, this can be an important consideration. An additional benefit of polled TDM is its module commonality - one type of module being used at central and a second type in the field. Strapping of the module provides the decoding

necessary for each unique remote site address. FDM requires a different receiver and transmitter for each frequency used. In an 18 channel system, therefore, 36 different types of modules would have to be stocked. The commonality impacts the size of the spare inventory.

It is very difficult to estimate costs for the TDM supervisory systems because virtually all of them are customized by manufacturers to serve a particular user's need. The amount of hardware required can be significantly reduced if a central computer is available for encoding, decoding, and error detection. These systems are more complex than FDM or TDM scanner systems, and maintenance and troubleshooting are more complicated.

This type of system should only be considered if several remote sites are involved, each with many data to transmit or receive.

Appendix E provides a summary of modulation techniques and some typical equipment costs. Most communication equipment will be customized by the vendor to meet user requirements, and cost and power consumption figures may vary widely from those shown in Appendix E. The cost figures do not include cabinet, card cage, nor installation costs. These costs will depend upon equipment configuration. Also included in Appendix E is a listing of communications equipment offered by manufacturers along with current users.

7-3 VOICE COMMUNICATIONS

a. INTRODUCTION

The Highway Advisory Radio (HAR)[1] technique has potential for providing guidance in the form of voice communications to motorists under reduced visibility conditions. The technique provides a means of transmitting highway and driving related messages to the motorist using an automobile AM radio receiver. Typically, the service is provided at frequencies of 530 and 1,610 kHz which are sufficiently close to the commercial AM broadcast band so that the majority of existing AM receivers can tune to them.

HAR systems have been installed for providing motorist information at airports, national parks, amusement parks, bridges, tunnels and highways. A system is currently operational on I-80 in Wyoming which provides auxiliary information in conjunction with a reduced visibility guidance system.

Systems to date have been authorized by the Federal Communications Commission (FCC) on a developmental license, under FCC Rules and Regulations, Part 15, which permits operation with restrictions which limit the transmitter power output and/or maximum field strength. The FCC, after several years of hearings, in recognition of the potential benefits to be derived from HAR, amended Parts 2 and 89 of its Rules and Regulations, effective 29 July 1977, to establish this service permanently.

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[1]The FCC does not use the HAR designation; instead it uses a broader term "Traveler's Information Station" (TIS), of which HAR is one application.

b. HAR SYSTEM ELEMENTS

A block diagram of a typical centrally-controlled HAR system having four channels is presented in Figure 28. The basic system elements are:

- Tape Recording and Playback Units
- Central Control Panel
- Communication Interface and Network
- Radio Transmitters
- Advisory Signs
- Antennas.

The Tape Recorder and Tape Playback Unit are located and controlled at the central location. The Tape Playback Units could also be located at the remote field site where they would be controlled locally. The Central Control Panel provides the means for selecting the logic states which are transmitted for controlling the on-off status of the transmitters and advisory signs. As previously described in paragraph 7-2b, the communication medium for both voice and control data can be leased lines, owned cable, or radio (microwave) transmission. The modulation technique for the transmission of the control data can be DC, FDM, or TDM, as previously described in paragraph 7-2c. The Radio Transmitters are amplitude-modulated by the audio signal from the tape players. Transmitters, limited to 50 watts for the leaky antenna and ten watts for the vertical antenna, should be housed in a locked weatherproof housing.

Two antenna configurations can be used in HAR installations: one consisting of a cable radiator, normally buried in the ground, and the other being a whip or monopole (vertical) antenna. The FHWA program on Highway Advisory Information Radio[1] included some field testing of both antenna types at the contemplated frequencies for roadside radio. Generally, the results indicated better performance for the cable radiator. The referenced report included a list of advantages and disadvantages for each type as listed below:

- Whip Antenna
  - physically small and can be installed in a relatively small space
  - relatively easy to install; can be installed in a short time in various environments over earth or pavement, on a building or tower, etc
  - portable and easily relocated to other sites

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[1]Study and Development of Highway Advisory Information Report, Final Report, December 1974, Report No. FHWA-RD-74-73

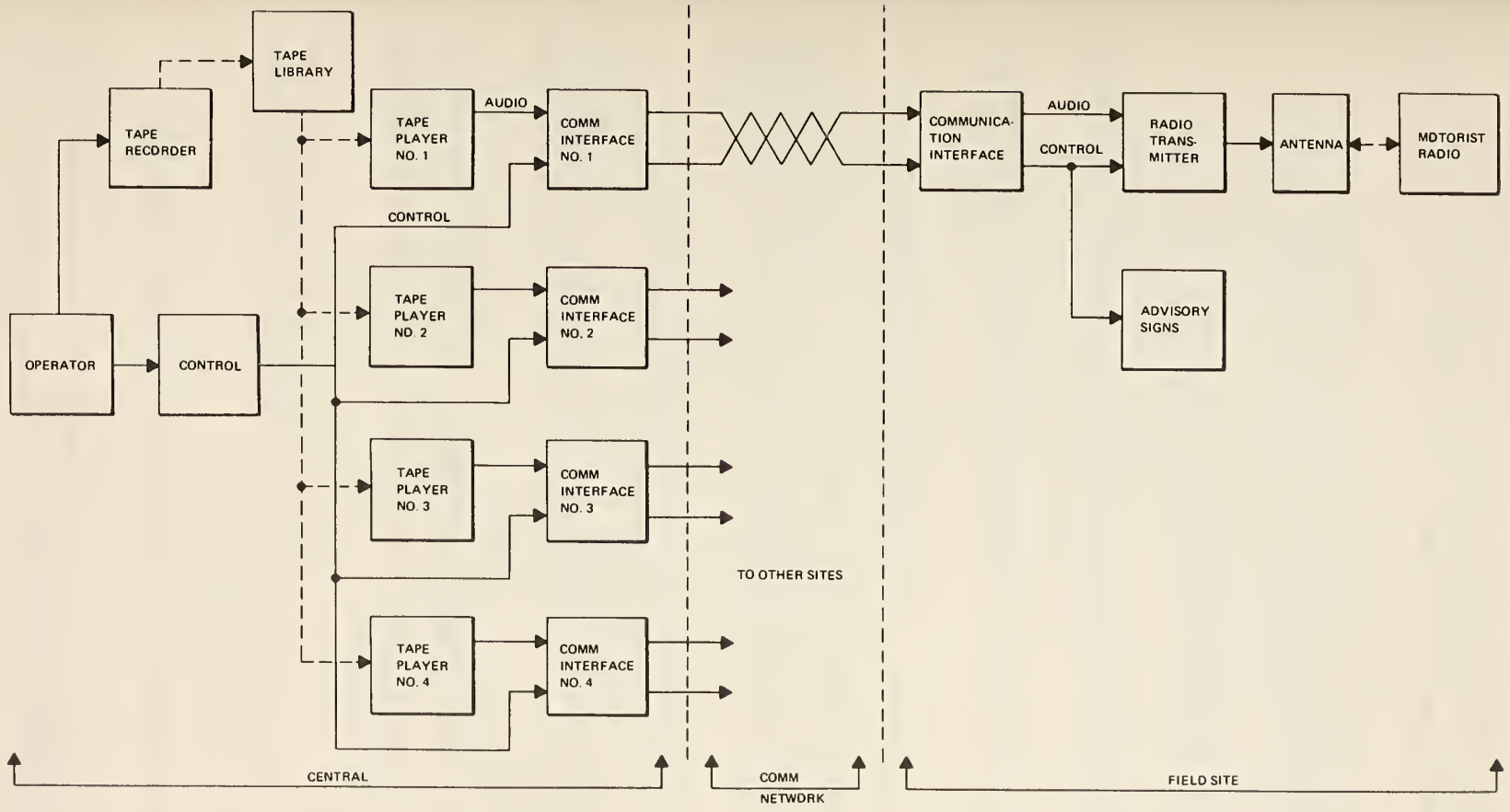

Figure 28. Centrally-Controlled Highway Advisory Radio System

- will usually be visible, but can be camouflaged to some degree
- can be placed several hundred feet from the highway
- subject to damage by weather, accident, or vandalism
- requires a matching network (or series inductance) that is efficient stable, reliable and easily tuned
- provides a circular zone of coverage that may interfere with other coverage zones on adjacent highways
- coverage zone extends well beyond the limits of the intended zone (highway application) and thus may overlap with other coverage zones on the same highway
- will usually be less costly to purchase and install than a cable antenna

• Cable Radiator

- must physically extend the full length of the coverage zone
- may be emplaced above or below ground
- can provide continuous coverage through tunnels, in buildings, under overpasses, etc
- is more costly to purchase and install, especially if buried
- is not easily relocated, especially if buried
- is not easily installed in some areas already built up with concrete pavement and highway structures, such as through a highway interchange or intersections
- can be made invisible, especially if buried
- cable antenna is easily connected electrically and requires no matching network or tuning adjustment
- radiation zone is confined to within 100 feet (30.5 m) or less from the cable and, thus, minimizes interference with nearby coverage zones
- must be placed close to the highway
- installed below ground, it is not subject to damage by weather or vandalism
- radiation pattern is stable with temperature and weather and is relatively unaffected by type of soil if buried.

Advisory signs are used in conjunction with HAR to identify the radio zone and to provide tuning information. The following are signing guidelines suggested by FHWA[1].

- Two signs should be placed preceding each HAR zone: first sign one mile (1.6 km) before beginning of zone with the following legend: RADIO TRAFFIC INFORMATION ONE MILE; the second sign at the start of the zone with the following legend: TRAFFIC INFORMATION, TUNE RADIO TO (frequency). When the system does not operate continuously, either blankout or variable message signs should be utilized or a yellow light designed to flash when the system is on and the words WHEN FLASHING should be added at the beginning of the message

- A sign should be placed at the end of each HAR zone with the following legend: END RADIO TRAFFIC INFORMATION

- Black on yellow is the suggested color combination for the RVG HAR application.

c. HAR SYSTEM COST ESTIMATE

Cost estimates have been developed for a single channel HAR installation covering a roadway length of about one mile (1.6 km) for the two antenna configurations (roadside radiator and whip). A summary is presented in Table 14. These costs do not include the communication links to central, since these are treated as part of the overall communications system.

The cost of a four-channel system such as is depicted in Figure 28, is essentially four times the estimated cost for each channel or about $80,000 for the roadside antenna and $30,000 for the whip antenna system. The added cost for the control console for the multi-channel configuration is more or less offset by the fact that only a single recorder is required.

Many manufacturers were reluctant to invest the capital in developing and building HAR equipment until the FCC promulgated rules and regulations governing this service. Now that this action has been taken, it is expected that there will be a significant increase in competition resulting in better performance at a lower cost.

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[1]FHWA Notice N5180.8 October 12, 1977, Highway Advisory Radio

TABLE 14. UNIT COST ESTIMATE FOR ROADSIDE RADIO

Item	Cost ($)
Single Channel Broadcast System (including loop cartridge recorder and playback unit)	3,000
Foundation (to support cabinet including anchor bolts)	300
Roadside Radiator — 5,000 feet (1.52 km) typical	
Material: Cable cost = $1.50 per foot x 5,000 feet = $7,500	
*Installation: Cable burial cost is $1.00 per foot x 5,000 feet = $5,000	12,500
	or
Whip Antenna installed (including matching network)	750
System Signing (identify radio zone and provide tuning instructions)	3,000
System Installation and Test	500
System Totals	
Cable Radiator	19,350
Whip Antenna	7,550

Notes

*Roadside radiator cable is installed by direct burial, six to eight inches (15.2 cm to 20.3 cm) in depth, in soft earth

d. SUMMARY OF FCC RULES AND REGULATIONS PERTAINING TO HAR SYSTEMS

The following is a summary of FCC rules pertaining to HAR systems:

- Transmitting site of each station shall be limited to the immediate vicinity of interstate highway interchanges, bridges, and tunnels
- Only noncommercial voice information pertaining to traffic and road conditions, traffic hazards, and travel advisories may be broadcast
- The stations's transmitting site shall be located at least 9.3 miles (15 km) outside the measured 0.5 mv/m daytime contour of any AM broadcast station operating on a first adjacent channel (540 kHz or 1,600 kHz)

- The station shall not interfere with broadcast stations operating on 550 kHz, 560 kHz, 1,580 kHz or 1,590 kHz

- For a cable antenna station the length of the cable shall not exceed 1.9 miles (3.0 km), and the field strength of the emission on the operating frequency shall not exceed 2 mv/m at a distance of 197 feet (60 m)

- For a vertical antenna station, the antenna height above ground shall not exceed 49.2 feet (15.0 m)

- The field strength shall not exceed 2 mv/m at a distance of 0.93 mile (1.5 km) from the antenna

- When several stations are operating on the same frequency but under different licenses, the following minimum separation distances apply:

  - both stations cable antennas - 0.31 mile (0.50 km)
  - one station vertical antenna, other cable - 4.66 miles (7.50 km)
  - both vertical antennas - 9.3 miles (15 km)

If the above distances are not met, the state government involved should coordinate the operation of the two systems to eliminate mutual interference. The above minimum distances do not apply when both stations are operating as part of a system. Normally, the operating agency is only permitted to utilize a single transmitter for each license issued. However, a system of stations, with each station in the system employing a separate transmitter, may be authorized for a specific area provided sufficient need is demonstrated by the applicant.

Appendix A

VISIBILITY DETECTION AND MEASUREMENT EQUIPMENT TABLE OF MANUFACTURERS AND COSTS

This appendix lists the manufacturers and costs for the following visibility detection and measurement equipment. (Refer to Table A-1.)

- Transmissometers and sensors
- Forward scatter devices
- Total scatter devices
- Side scatter devices
- CCTV detectors
- Backscatter devices.

TABLE A-1. VISIBILITY DETECTION AND MEASUREMENT EQUIPMENT

TRADE NAME	DISTRIBUTOR/MANUFACTURER	PURCHASE PRICE	OPERATING COSTS
TRANSMISSOMETERS AND SENSORS			
FOG SENSOR (PROTOTYPE)	PHOTOBELL, NEW YORK	PROTOTYPE, $12K; PRODUCTION ESTIMATE, $2,000	N/A
HELIOS	AERAZUR CONSTRUCTIONS ELECTRONIQUE MONTROUGE	N/A	N/A
SKOPGRAPH	FF IMPULSPHYSICS CORP. CAPE CORAL, FLORIDA	$26,125 CIF* INCLUDING RECORDER, $24,600 CIF* WITH DIRECT INDICATOR AND ALARM RELAY. (INCLUDES CALIBRATION KIT)	REPLACE FLASH LAMP 2-3 YEARS, $550. INSTALLATION COST RELATIVELY LOW. REQUIRES ROUTINE CLEANING OF WINDOWS. ALL SOLID STATE.
SKOPOGRAPH	SAME AS ABOVE	SAME AS ABOVE	SAME AS ABOVE BUT FRANGIBLE STRUCTURE WITH BLOWER PROTECTED WINDOWS REQUIRING LOW CLEANING CYCLE.
RM-41 OPACITY METER (PRIMARILY FOR STACK MEASUREMENTS) SHORT BASELINE ONLY.	LEAR SIEGLER, ATLANTA, GEORGIA	$4,695 FOB BASIC, $9,500 FOB INCLUDING AUTOMATIC CALIBRATOR AND FAILSAFE. NO RECORDER OR ALARM RELAY.	LOW COST TUNGSTEN LIGHT SOURCE. REQUIRED ROUTINE CLEANING OF WINDOWS.
SM4 (VM4) VISIBILITY METER	LEAR SIEGLER	$15K TO $20K	SIMILAR TO RM-41.
MODEL 172B (NOT OFF-THE-SHELF)	COLORADO ELECTRO-OPTICS BOULDER, COLORADO	$2,950 FOB WITH ALARM RELAY. NO RECORDER	GaAs LIGHT SOURCE. TYPICAL TRANSMISSOMETER INSTALLATION COSTS AND ROUTINE CLEANING.
WM73-T	WEATHER MEASURE SACRAMENTO, CALIFORNIA	$13,905 FOB, RECORDER $1,416 PEDESTAL $139 EACH, MULTIPOINT ALARM $1,892 FOB, CALIBRATOR $386, FIELD TEST KIT $360, OUTPUT TEST $669.	LED LIGHT SOURCE

NOTE
*CIF = COST INSURANCE AND FREIGHT

N/A = NOT APPLICABLE

Table A-1. Visibility Detection and Measurement Equipment (Continued)

TRADE NAME	DISTRIBUTOR/MANUFACTURER	PURCHASE PRICE	OPERATING COSTS
VISIBILITY SENSOR MODEL VS-1	INTERNATIONAL LASER SYSTEMS, ORLANDO, FLORIDA	$6,750 FOB 25 OR MORE $4,250 (WITH FOUR RELAYS)	INSTALLATION $250 PLUS TRANSPORTATION. LASER DIODE LIGHT (INFRARED) SOURCE. LOW MAINTENANCE. ROUTINE OPTICS CLEANING REQUIRED. USER MUST SUPPLY MOUNTING.
7M-15-150D	ELTRO GmbH HEIDELBURG, WEST GERMANY (AEG-TELEFUNKEN, SCHENECTADY)	DM69,900 FOB HEIDELBURG 15 TO 20 PERCENT DUTY	N/A
SM-5	MARCONI RADAR SYSTEMS UNITED KINGDOM	TRANSMISSOMETER $9,195 FOUR POINT ALARM AND CONTROL $1,850 PROTECTIVE HOUSING $1,935 CALIBRATION KIT $1,250	N/A
MODEL 500	TASKER INDUSTRIES LOS ANGELES, CALIFORNIA	$25,000 FOB INCLUDING RECORDER	ALL SOLID STATE LOW MAINTENANCE, REPLACE LAMP EVERY 10,000 HOURS, COST $10.
HAMAMATSU UV TRANSMISSOMETER	HAMAMATSU TV CO. LTD. MIDDLESEX, NEW JERSEY	N/A	N/A
LYNX	SNECMA, ELECMA DIV. SURENES, FRANCE	$12,000 FOB NO OUTPUT DEVICE NO OUTPUT DEVICE	N/A
MET-1	MARCONI RADAR UNITED KINGDOM	$10,000 FOB	N/A
	NOTE: PRICE BASED ON 1975 LEAR SIEGLER FOB. LEAR SIGLER NO LONGER MARKETS.		
TRRL FOG DETECTOR	B.E.L. DEVELOPMENTS, LTD., ENGLAND	$1,650 FOB	N/A
TRANSMISSOMETER SIAP TA 6006	SIAP, ITALY	N/A	N/A

NOTE
N/A = NOT APPLICABLE
DM = DEUTSCHE MARK (GERMAN CURRENCY)

Table A-1. Visibility Detection and Measurement Equipment (Continued)

TRADE NAME	DISTRIBUTOR/MANUFACTURER	PURCHASE PRICE	OPERATING COSTS
FORWARD SCATTER DEVICES			
FUMOSENS III	FF IMPULSPHYSICS CORP.	$5,100 CIF* INCLUDING ONE ALARM RELAY. TEN PERCENT REDUCTION FOR 20 OR MORE.	VERY LOW. ALL SOLID STATE. PROTECTED WINDOWS REQUIRE LOW CLEANING CYCLE. LAMP REPLACEMENT 2 TO 4 YEARS.
FSM MODEL 207	EG&G, WALTHAM, MASSACHUSETTS	$9,800 FOB, CALIBRATOR $1,800; 30 PERCENT REDUCTION FOR 20 OR MORE.	MTBF 1 YEAR. REQUIRES 0.5 MANDAY TO REPLACE MOTOR BEARINGS EACH YEAR.
PVM	PLESSEY RADAR, ENGLAND	£3100 FOB, £800 FOR CALIBRATOR, 15 TO 20 PERCENT DUTY.	VERY LOW INSTALLATION COSTS. USES LED. MONTHLY ROUTINE MAINTENANCE. ALL SOLID STATE.
TOTAL SCATTER DEVICES			
AEG/FFM	AEG TELEFUNKEN SCHENECTADY, NEW YORK	DM24,100 FOB. FOG ALARM DM1,650. SELF ALIGNMENT DM1,710. DIGITAL TO ANALOG CONVERTER DM1,770. CONVERTER DM1,970.	NEW MODEL, APPROXIMATES TOTAL SCATTER BY MEASURING 10° TO 120° SCATTER.
SIDE SCATTER DEVICES			
MODEL 1580 VISIOMETER	MRI, ALTADENA, CALIFORNIA	$4,985 FOB WITHOUT RECORDER OR RELAYS.	VERY LOW INSTALLATION AND MAINTENANCE COSTS. REPLACE LAMP ONCE PER YEAR AT $15. SPARE CARDS $1,500. ALL SOLID STATE.
CCTV DETECTORS			
VIDEOMETER	ATELIERS DE CONSTRUCTIONS ELECTRIQUES DE CHALEROI BELGIUM	N/A	N/A

NOTES
- *CIF = COST INSURANCE AND FREIGHT
- N/A = NOT APPLICABLE
- £ = ENGLISH POUNDS (CURRENCY)
- DM = DEUTSCHE MARK (GERMAN CURRENCY)
- MTBF = MEAN-TIME-BEFORE-FAILURE

Table A-1. Visibility Detection and Measurement Equipment (Continued)

TRADE NAME	DISTRIBUTOR/MANUFACTURER	PURCHASE PRICE	OPERATING COSTS
BACKSCATTER DEVICES			
VIDEOGRAPH	FF IMPULSPHYSICS CORP. CAPE CORAL, FLORIDA	$13,000 CIF*, CALIBRATOR $2,000 (INCLUDING ALARM RELAY).	REPLACE FLASH LAMP 2 TO 4 YEARS, $550. INSTALLATION VERY LOW.
SATT FD 300	SATT ELEKTRONIK AB STOCKHOLM, SWEDEN	$9,000 FOB, 15 TO 20 PERCENT DUTY.	LED LIGHT SOURCE (INFRARED). NO HEATERS REQUIRED, LOW POWER. SELF-COMPENSATION FOR DIRT ON WINDOWS.
WM74-F	WEATHER MEASURE SACRAMENTO, CALIFORNIA	$4,500 FOB, PEDESTAL $95.	LED LIGHT SOURCE (INFRARED). OPERATING COSTS N/A.
ASEA	ASEA, SWEDEN	N/A	N/A
FOGNAL	MEISEI ELECTRIC COMPANY JAPAN	N/A	N/A

NOTES
*CIF = COST INSURANCE AND FREIGHT
N/A = NOT APPLICABLE

Appendix B

CLOSED CIRCUIT TELEVISION EQUIPMENT TABLE OF MANUFACTURERS, COSTS, AND CHARACTERISTICS

This appendix lists CCTV equipment manufacturers and costs, with descriptions of the equipment used.

TABLE B-1. CCTV EQUIPMENT

MANUFACTURER	CAMERA TUBE	SPECTRAL RESPONSE (ANGSTROMS)	CAMERA PRICE ($)	MONITOR PRICE ($)	OPERATING COSTS AND REMARKS
COHU	NEWVICON	4 TO 8 (PEAKS AT 5.5)	2,400 1,800	ELECTRAHOME 300 to 350. CONRAC 600 TO 700.	SPECIAL ENVIRONMENTAL CAMERA, REGULAR CAMERA IN ENVIRONMENTAL HOUSING. MTBF 16,880 HOURS. TYPICAL MAINTENANCE 0.5 MANDAY PER YEAR.
GE	SILICON (EPICON VACUUM)	VISIBLE AND INFRARED	650 LENS 200		REPLACE TUBE ($350) EVERY 2 YEARS. LOW BLOOM TYPE. AUTO-IRIS REQUIRED. TE45 OUTDOOR CAMERA.
	VIDICON	VISIBLE	320 LENS 13		TUBE SUBJECT TO BURNING FROM BRIGHT LIGHTS. LOW COST ($20). DOES NOT REQUIRE AUTO-IRIS.
	CCD OR CID	VISIBLE	2,000 W/LENS		SOLID STATE VIDICON FOR LOW LIGHT LEVEL. POOR RESOLUTION.
HAMAMATSU	NEWVICON	4 TO 11	1,000 TO 2,300	300 TO 350	SILICON TARGET VIDICON (LOW BLOOM SILICON). REPLACE TUBE APPROXIMATELY ONCE PER YEAR AT $400 TO 450. ADJUST CAMERA ONCE PER MONTH, CLEAN LENS, ETC.
	SITCON		2,300 EXTRA POWER SUPPLY 3,500		
MOTOROLA	SILICON HETERO-JUNCTION	PEAKS 6 TO 7	7,200 WITH LENS AND OUTDOOR HOUSING	12 INCHES, HIGH PERFORMANCE 325. 23 INCHES, HIGH PERFORMA-ANCE 450.	DIODE ARRAY VIDICON. NO BLOOM. SERVO CONTROL NEUTRAL DENSITY FILTER.

NOTES:

ONE ANGSTROM = 10^{-8} CM = 3.93×10^{-9} INCHES
MTBF = MEAN-TIME-BEFORE-FAILURE

Table B-1. CCTV Equipment (Continued)

MANUFACTURER	CAMERA TUBE	SPECTRAL RESPONSE (ANGSTROMS)	CAMERA PRICE ($)	MONITOR PRICE ($)	OPERATING COSTS AND REMARKS
MOTOROLA (Continued)	SILICON DUAL INTENSIFIED VIDICON	PEAKS 7 TO 9	10,300 TO 13,300		SUBJECT TO BLOOMING. RECOMMENDED FOR VERY LOW LIGHT LEVEL ONLY.
RCA	SITCON	FULL FLAT SPECTRUM	5:1 ZOOM 7,425. 8:1 ZOOM 7,725. 10:1 ZOOM 8,850. STANDARD LENS 6,825.	(9 INCHES) 235. (12 INCHES) 285. (17 INCHES) 330.	BEST FOR LOW LIGHT LEVEL. MTBF 18,000 HOURS. REPLACEMENT TUBE $1,900
	SILICON	PEAKS AT 9 VISIBLE & IR	1,250, AUTO IRIS LENS 500.		SILICON BLOOMS WHEN HIT BY LIGHT SOURCE. REPLACEMENT TUBE $550.
	NEWVICON	4 TO 8	SAME AS SITCON.		NEWVICON TUBE OK IF LOOKING AT LIGHT SOURCE, BUT WILL BURN IN TIME IF SOURCE DOES NOT MOVE.
	VIDICON .....NOT RECOMMENDED FOR OUTDOOR USE				
SONY	VIDICON	VISIBLE	375 INCLUDING LENS.	(8 INCHES) 295 (11 INCHES) 315 (19 INCHES) 375	AVC 1400 SURVEILLANCE CAMERA. NO ENVIRONMENTAL HOUSING.
	NEW TYPE	—	1,195, LENS 550.	SAME AS VIDICON	AVC 1450 LOW LIGHT SURVEILLANCE CAMERA. AUTO-DIAPHRAGM LENS REQUIRED.
LAKE SYSTEMS	SITCON	VISIBLE THROUGH INFRARED	11,000 TYPICAL.	350	FAST ZOOM LENS, WEATHER PROOF. PAN AND TILT. OPERATING COSTS 10 PERCENT PER YEAR OF SELLING PRICE. 6 MONTHS TO 1 YEAR WARRANTY ON TUBE. SILICON TUBE $500 TO $600. SITCON TUBE $2,000. CAMERA PRICES INCLUDE COSTS OF CONTROLS FOR PAN, ZOOM, TILT.
	SILICON	VISIBLE THROUGH INFRARED	5,500 TYPICAL.		
	VIDICON.....NOT USABLE				

NOTES: ONE ANGSTROM = 10^{-8} cm = 3.93×10^{-9} INCHES; MTBF = MEAN-TIME-BEFORE-FAILURE

Appendix C

INDUCTIVE LOOP, MAGNETIC, AND MAGNETOMETER VEHICLE DETECTOR EQUIPMENT

This appendix lists and describes the manufacturers and their respective equipment specifications for loop detector and magnetic and magnetometer units.

TABLE C-1. LOOP DETECTOR ELECTRONICS SPECIFICATIONS

COMPANY	MANUFACTURER SUGGESTED MODEL AND UNIT COST[1]	SIZE[2]	POWER	OPERATIONAL RANGE
CANOGA CONTROLS	400 SERIES: MODEL 402: $319 MODEL 404: $385 ($5 EXTRA/CHANNEL FOR RELAY OUTPUT)	CASE: 2.25 BY 6 BY 9 (6 BY 15 BY 23)	115 VAC 8 WATTS MAX. 4 TO 5 WATTS AVG.	-35° F, 165° F (-37° C, 74° C) 0-99% HUMIDITY 0-2,000 MICROHENRIES MAX LEAD-IN OVER 1,000 FEET (305 M)
CANOGA CONTROLS	420 SERIES: MODEL 422: $352 MODEL 424: $319 MODEL 424D: $407 TO $451 (DEPENDENT UPON OPTIONAL OUTPUT FUNCTIONS)	PLUG-IN BOARD: MODEL 422: 1.2 BY 4.5 BY 8 (30 BY 115 BY 205) MODEL 424 AND 424D: 2 BY 4.5 X 8 (50 BY 115 BY 205)	24 VDC 8 WATTS MAX. 4 TO 5 WATTS AVG.	SEE ABOVE
DECATUR ELECTRONICS	MODEL AF: $200 MODEL XL: $180 $5 EXTRA FOR SS OUTPUT	CASE: 7.25 BY 3 BY 5 (185 BY 75 BY 125)	115 VAC APPROX. 10 WATTS	-20° F, 170° F (-29° C, 77° C) MAX. LEAD-IN: 1,000 FEET (305 M) 50 TO 700 MICRO-HENRIES
DECATUR ELECTRONICS	SENTRY IV: $160	CASE: 2.1 BY 5.5 BY 6.5 (55 BY 140 BY 165)	115 VAC OR 12 VDC APPROX. 10 WATTS	-40° F, 170° F (-40° C, 77° C) 20 TO 700 MICROHENRIES MAX LEAD: 750 FEET (230 M)
DECATUR ELECTRONICS	C III A: $160	CASE: 4.75 BY 2.5 BY 6 (120 BY 65 BY 150)	115 VAC APPROX 10 WATTS	-20° F, 170° F (-29° C, 77° C) MAX LEAD: 1,000 FEET (305 M) 50 TO 700 MICRO-HENRIES
EAGLE	EW120: $169	CASE: 5 BY 2.9 BY 6 (12.5 BY 7.5 BY 15)	115 VAC 5 WATTS	-33° F, 165° F (-35° C, 74° C) 50 To 800 MICROHENRIES

NOTES
[1] COST INCLUDES HARNESS FOR CASE UNITS BUT DOES NOT INCLUDE POWER SUPPLY OR CARD RACK FOR CARDS.
[2] DIMENSIONS ARE GIVEN IN INCHES (FOLLOWED BY CENTIMETERS IN PARENTHESES) FOR WIDTH, HEIGHT, AND DEPTH, RESPECTIVELY.

Table C-1. Loop Detector Electronics Specifications (Continued)

COMPANY	MANUFACTURER SUGGESTED MODEL AND UNIT COST[1]	SIZE[2]	POWER	OPERATIONAL RANGE
ENERCO	121 SERIES: MODEL 121: $1,120 MODEL 122: $1,720	CASE: 4 BY 6 BY 11 (10 BY 15 BY 28)	115 VAC 18 WATTS	-20° F, 160° F (-29° C, 71° C) EXCEEDS 100 TO 1,000 MICROHENRIES
SARASOTA	215 SERIES: MODEL 215B: $108 MODEL 225D: $142 MODEL 225S: $142	CASE: 2 BY 6 BY 6 (5 BY 15 BY 15)	115 VAC 5 WATTS	-40° F, 180° F (-40° C, 82° C) 20 TO 700 MICROHENRIES MAX LEAD-IN: 1,000 FEET (305 M)
FOSCO	–	–	–	–
INDICATOR CONTROLS	3010-7 SERIES: MODEL 7: $105 MODEL 8: $105 MODEL 9: $113 MODEL 45: $121 MODEL 55: $121 MODEL 65: $137	CASE: 2 BY 5.25 BY 5.5 (5 BY 13.5 BY 14)	115 VAC 1.2 WATTS	-35° F, 180° F (-37° C, 82° C) 50 TO 1,000 MICROHENRIES MAX. LEAD-IN: 1000 FEET (305 M)
INDICATOR CONTROLS	3010-20 SERIES: -20: $138 -40: $207	PLUG-IN BOARD: 1.17 BY 4.5 BY 8 (3 BY 11.5 BY 205)	24 VDC 1.5 WATTS/ CHANNEL	-35° F, 180° F (-37° C, 82° C) 50 TO 500 MICROHENRIES

NOTES
[1] COST INCLUDES HARNESS FOR CASE UNITS BUT DOES NOT INCLUDE POWER SUPPLY OR CARD RACK FOR CARDS.
[2] DIMENSIONS ARE GIVEN IN INCHES (FOLLOWED BY CENTIMETERS IN PARENTHESES) FOR WIDTH, HEIGHT, AND DEPTH, RESPECTIVELY.

Table C-1. Loop Detector Electronics Specifications (Continued)

COMPANY	MANUFACTURER SUGGESTED MODEL AND UNIT COST[1]	SIZE[2]	POWER	OPERATIONAL RANGE
INDICATOR CONTROLS	3040 SERIES: MODEL 3040: $322 MODEL 3044: $359	CASE: 2.9 BY 6.25 BY 8.9 (7.5 BY 16 BY 22.5)	115 VAC 13 WATTS	-35° F, 180° F (-37° C, 82° C) 50 TO 650 MICROHENRIES
INDICATOR CONTROLS	MODEL 3024: $154	PLUG-IN BOARD: 0.9 BY 4.5 BY 8.2 (2.5 BY 11.5 BY 21)	24 VDC 2.5 WATTS	-35° F, 180° F (-37° C, 82° C)
STREETER-AMET	MODEL 740: $140	CASE: 2 By 6 BY 6 (5 BY 15 BY 15)	115 VAC	-40° F, 180° F (-40° C, 82° C) 40 TO 700 MICROHENRIES MAXIMUM LEAD-IN 1,000 FEET (305 M)
STREETER-AMET	MODEL 750: $215	CASE: 2.5 BY 6 BY 7 (6.5 BY 15 BY 18)	115 VAC OR 112 VDC	-40° F, 180° F (-40° C, 82° C) 40 TO 700 MICROHENRIES MAXIMUM LEAD-IN 1,000 FEET (305 M)
TDS	LDM 340 PRICE IS BID ONLY	PLUG-IN BOARD: 1.2 BY 5.25 By 7.5 (3 BY 13.5 BY 19)	25 VDC 1 WATT	-35° F, 165° F (-37° C, 74°C) 0 TO 99 PERCENT HUMIDITY 50 TO 400 MICROHENRIES
TDS	LD 328: $120	CASE: 2.5 BY 5.2 BY 7 (6.5 BY 13 BY 18)	115 VAC 3 WATTS	-30° F, 165° F (-34° C, 74° C) 0 TO 99 PERCENT HUMIDITY 45 TO 500 MICROHENRIES
TDS	LD 356, 357, 360: $120	CASE: 2.5 BY 5.2 BY 7 (6.5 BY 13 BY 18)	115 VAC (1V VDC OPTIONAL FOR MODEL 355) 3 WATTS	-30° F, 165° F (-34° C, 74° C) 0 TO 99 PERCENT HUMIDITY 60 TO 450 MICROHENRIES (MODEL 355). 70 TO 500 PERCENT MICROHENRIES (MODELS 356, 357)

NOTES
[1]COST INCLUDES HARNESS FOR CASE UNITS BUT DOES NOT INCLUDE POWER SUPPLY OR CARD RACK FOR CARDS.
[2]DIMENSIONS ARE GIVEN IN INCHES (FOLLOWED BY CENTIMETERS IN PARENTHESES) FOR WIDTH, HEIGHT, AND DEPTH, RESPECTIVELY.

TABLE C-2. LOOP DETECTOR FEATURES

COMPANY	MFR. SUGGESTED MODEL AND UNIT COST[1]	CIRCUIT FEATURES	TUNING FEATURES	COMMENTS
CANOGA CONTROLS	400 SERIES: MODEL 402: $319 MODEL 404: $385 ($5 EXTRA/CHANNEL FOR RELAY OUTPUT)	DIGITAL SS ELECTRONICS RELAY OR SS OUTPUT PULSE OR PRESENCE OUTPUT. 2 OR 4 CHANNELS. SEQUENTIAL SCANNING.	SELF TUNING, AUTO TRACKING, 8 SENSITIVIES, 3 FREQUENCIES, MAX SENSITIVITY LESS THAN 0.01 PERCENT.	
CANOGA CONTROLS	420 SERIES: MODEL 422: $352 MODEL 424: $319 MODEL 424D: $407 TO $451 (DEPENDENT UPON OPTIONAL OUTPUT FUNCTIONS)	SEE ABOVE. ALSO: DELAY, EXTENSION, AND MIN. GREEN TIMERS FUNCTIONS AVAILABLE.	SEE ABOVE.	
DECATUR ELECTRONICS	MODEL AF: $200 MODEL XL: $180 $5 EXTRA FOR SS OUTPUT	OPTIONAL SS OUTPUT (AF ONLY). PULSE OR PRESENCE OUTPUT.	64 FREQUENCIES (AF). FREQUENCY CONTROLLED BY PLUG-IN CRYSTAL (XL). CONSIDERABLE DRIFT CAPABILITY. 3 SENSITIVITIES.	
DECATUR ELECTRONICS	SENTRY IV: $160	OPTIONAL SS OUTPUT. PULSE OR PRESENCE OUTPUT DELAY, EXTENSION, OPTIONAL. CALIFORNIA CIRCUIT OPTIONAL.	0.02 PERCENT SENSITIVITY. 5 PERCENT DRIFT TOLERANCE. 3 FREQUENCIES.	
DECATUR ELECTRONICS	C III A: $160	PULSE OR PRESENCE OUTPUT. OPTIONAL SS OUTPUT.	SELF TUNING. 2 FREQUENCIES.	
EAGLE	EW120: $169	PULSE OR PRESENCE OUTPUT. RELAY OUTPUT.	AUTOMATIC TRACKING. FULL RANGE OF SENSITIVITIES. MAX. SENSITIVITY 0.02 PERCENT 2 FREQUENCIES.	

NOTE

[1] COST INCLUDES HARNESS FOR CASE UNITS BUT DOES NOT INCLUDE POWER SUPPLY OR CARD RACK FOR CARDS.

Table C-2. Loop Detector Features (Continued)

COMPANY	MFR. SUGGESTED MODEL AND UNIT COST[1]	CIRCUIT FEATURES	TUNING FEATURES	COMMENTS
ENERCO	121 SERIES: MODEL 121: $1,120 MODEL 122: $1,720	8 CIRCUITS (MODEL 121), 16 CIRCUITS (MODEL 122). DIGITAL SOLID STATE ELECTRONICS. SEQUENTIAL SCANNING. PULSE OR PRESENCE OUTPUT. SOLID STATE OUTPUT. CARD-TYPE INTERFACE PLUG.	AUTOMATIC TUNING. AUTOMATIC TRACKING. 4 SENSITIVITIES. MAXIMUM SENSITIVITY: 0.01 PERCENT. 1 FREQUENCY.	
SARASOTA	215 SERIES: MODEL 215B: $108 MODEL 225D: $142 MODEL 225S: $142	PULSE OR PRESENCE OUTPUT. RELAY OUTPUT. DELAY FUNCTION (MODEL 225D), EXTENSION FUNCTION (MODEL 225S).	3 SENSITIVITIES. 3 FREQUENCIES. MAXIMUM SENSITIVITY: 0.02 PERCENT. AUTOMATIC TRACKING.	
FOSCO	–	–	–	DIGITAL LOOP DETECTOR TO BE MARKETED SOON.
INDICATOR CONTROLS	3010-7 SERIES: MODEL 7: $105 MODEL 8: $105 MODEL 9: $113 MODEL 45: $121 MODEL 55: $121 MODEL 65: $137	PRESENCE OF PULSE OUTPUT (SIMULTANEOUS FOR MODEL 65). DIGITAL SS ELECTRONICS. RELAY OUTPUT (MODELS 7, 45, 55, 65). SOLID STATE OUTPUT (MODEL 8). RELAY OR SS OUTPUT (MODEL 9). DELAY FUNCTION (MODELS 45, 65). EXTENSION FUNCTION (MODEL 55).	AUTOMATIC TUNING. AUTOMATIC TRACKING. 3 FREQUENCIES (EXCEPT MODEL 7B: 1 FREQUENCY. 3 SENSITIVITIES. MAXIMUM SENSITIVITY: 0.014 PERCENT.	
INDICATOR CONTROLS	3010-20 SERIES: -20: $138 -40: $207	2 CHANNELS (MODEL 20), 4 CHANNELS (MODEL 40). DIGITAL SS ELECTRONICS. SOLID STATE OUTPUT. PRESENCE OUTPUT. PULSE OUTPUT OPTIONAL (MODEL 20).	AUTOMATIC TUNING. AUTOMATIC TRACKING. 1 FREQUENCY/CHANNEL. 3 SENSITIVITIES. MAXIMUM SENSITIVITY 0.014 PERCENT.	MEETS CALIFORNIA AND NEW YORK STATE SPECIFICATIONS.

NOTE

[1] COST INCLUDES HARNESS FOR CASE UNITS BUT DOES NOT INCLUDE POWER SUPPLY OR CARD RACK FOR CARDS.

Table C-2. Loop Detector Features (Continued)

COMPANY	MFR. SUGGESTED MODEL AND UNIT COST[1]	CIRCUIT FEATURES	TUNING FEATURES	COMMENTS
INDICATOR CONTROLS	3040 SERIES: MODEL 3040: $322 MODEL 3044: $359	4 CHANNELS. DIGITAL SS ELECTRONICS. RELAY OUTPUT. PRESENCE OUTPUT. PULSE OUTPUT OPTIONAL (MODEL 44).	AUTOMATIC TUNING. AUTOMATIC TRACKING. 1 FREQUENCY/CHANNEL. MAXIMUM SENSITIVITY: 0.028 PERCENT'	MODELS MEET CALIFORNIA SPECIFICATIONS
INDICATOR CONTROLS	MODEL 3024: $154	DIGITAL SS ELECTRONICS. SOLID STATE OUTPUT. PRESENCE OUTPUT. DELAY, EXTENSION, AND INITIAL GREEN FUNCTIONS.	AUTOMATIC TUNING. AUTOMATIC TRACKING. 3 FREQUENCIES. 8 SENSITIVITIES. MAXIMUM SENSITIVITY: 0.014 PERCENT.	DESIGNED AS REPLACEMENT FOR FISCHER-PORTER DETECTOR EMPLOYED IN TYPE 100 CONTROLLER.
STREETER-AMET	MODEL 740: $140	RELAY OUTPUT. SIMULTANEOUS PULSE, PRESENCE OUTPUT.	5 PERCENT DRIFT COMPENSATION. 3 FREQUENCIES. 3 SENSITIVITIES. MAXIMUM SENSITIVITY: 0.02 PERCENT.	
STREETER-AMET	MODEL 750: $215	RELAY OR SS OUTPUT. 2 CHANNELS.	5 PERCENT DRIFT COMPENSATION. FULL RANGE OF SENSITIVITIES. MAXIMUM SENSITIVITY: 0.04 PERCENT, FIXED FREQUENCY FOR EACH CHANNEL.	TYPICALLY USED TO DETERMINE VEHICLE SIZE OR DIRECTION.
TDS	LDM 340 PRICE IS BID ONLY	SOLID STATE OUTPUT. PULSE OR PRESENCE OUTPUT.	AUTOMATIC TRACKING. 4 FREQUENCIES. 3 SENSITIVITIES. MAXIMUM SENSITIVITY: 0.02 PERCENT.	MEETS CALIFORNIA SPECIFICATIONS
TDS	LD 328: $120	RELAY OR SS OUTPUT. PULSE OR PRESENCE OUTPUT.	AUTOMATIC TRACKING. 4 FREQUENCIES. 2 SENSITIVITIES. MAXIMUM SENSITIVITY: 0.02 PERCENT.	
TDS	LD 356, 357, 360: $120	RELAY OR SS OUTPUT. PULSE OR PRESENCE OUTPUT.	AUTOMATIC TUNING. AUTOMATIC TRACKING. 1 FREQUENCY. SENSITIVITY: 0112 PERCENT. (MODELS 355, 356). FULL FULL SENSITIVITY RANGE (MODEL 357).	

NOTE

[1]COST INCLUDES HARNESS FOR CASE UNITS BUT DOES NOT INCLUDE POWER SUPPLY OR CARD RACK FOR CARDS.

TABLE C-3. MAGNETIC AND MAGNETOMETER DETECTOR SPECIFICATIONS

COMPANY	MODEL AND COST[1]	SIZE[2]	POWER	OPERATIONAL RANGE
EAGLE	EV5, EV6 MAGNETIC DETECTOR: $314	CASE: 2 BY 4 BY 6.25 (5 BY 10 BY 16)	115 VAC 2 WATTS AMPHEROL OR OCTAL PLUG CONNECTOR	-30°F, 160°F (-34° C, 71° C) 65 PERCENT HUMIDITY AT 160° F (71° C)
DECATUR	DEM-3 MAGNETIC DETECTOR: $138	CASE: 4 BY 2 BY 7.5 (10 BY 5 BY 19)	115 VAC ANY TYPE CONNECTOR	COMPARABLE TO COMPETITION
AUTOMATIC SIGNAL	MR-10 MAGNETIC DETECTOR: $165	CASE: 5 BY 2.12 BY 7.5 (13 BY 5 BY 19)	115 VAC 2 WATTS MS CONNECTOR	-30°F, 180° F (-34° C, 82° C)
CANOGA	PROXIMITOR MAGNETOMETER SERIES MODEL 202: $259 MODEL 222: $198	CASE: 2 BY 6 BY 9 (5 BY 15 BY 23) (PLUG-IN MODULE) 2 BY 4.5 BY 8 (5 BY 11 BY 20)	115 VAC 11 WATTS MAX. MS CONNECTOR 24 VDC (7.5 WATTS)	-30°F, 160° F (-34° C, 71° C) HUMIDITY 0 TO 100 PERCENT 5,000 FOOT LEAD-IN
GAMMATRONIX	MODEL 11MG MAGNETOMETER: $224	CASE: 4.62 BY 2.75 BY 8.5 (12 BY 7 BY 22)	115 VAC 5 WATTS	-30°F, 180° F (-34° C, 82° C)

NOTES
[1] COST LISTED IS MANUFACTURERS SUGGESTED UNIT PRICE. COST INCLUDES A HARNESS FOR CASE UNITS, BUT DOES NOT INCLUDE POWER SUPPLY OR CARD RACK FOR PLUG-IN BOARD UNITS.
[2] DIMENSIONS ARE GIVEN IN INCHES (FOLLOWED BY CENTIMETERS IN PARENTHESES) FOR WIDTH, HEIGHT, AND DEPTH, RESPECTIVELY.

TABLE C-4. MAGNETIC AND MAGNETOMETER DETECTOR FEATURES

COMPANY	CIRCUIT FEATURES	TUNING FEATURES	COMMENTS
EAGLE	SOLID STATE CIRCUITRY. PULSE OUTPUT ONLY.	FULL RANGE OF SENSITIVITIES. ANY NUMBER OF PROBES.	
DECATUR	SOLID STATE CIRCUITRY. PULSE OUTPUT ONLY.	FULL RANGE. ANY NUMBER OF PROBES.	MINIMUM SPEED: 3 MPH (5 KM/HR).
AUTOMATIC SIGNAL	SOLID STATE CIRCUITRY. PULSE OUTPUT ONLY.	FULL RANGE. ANY NUMBER OF PROBES.	MKA PROBE (SHORT RANGE): $120. MK PROBE (LONG RANGE): $80. MINIMUM SPEED: 3 MPH (5 KM/HR), WITHIN 2 FEET (0.7 M) OF LOOP).
CANOGA	TWO CHANNELS. PRESENCE OR PULSE OUT. EXTENSION AND DELAY FEATURES. RELAY OR SS OUTPUT. SOLID STATE CIRCUITRY.	FULL RANGE. 1 TO 12 PROBES PER CHANNEL.	NO MINIMUM SPEED. 0.94 BY 3.5 INCHES (2 CM BY 9 CM) CYLINDRICAL PROBE IS AVAILABLE FOR $40 WITH LEAD-IN CABLE AT 18 CENTS/FOOT (59 CENTS/METER).
GAMMATRONIX	PRESENCE OUTPUT. SOLID STATE CIRCUITRY.	FULL RANGE. RECOMMEND ONE PROBE.	NO MINIMUM SPEED. SENSOR: $69.

Appendix D

VARIABLE MESSAGE SIGN (VMS) EQUIPMENT PRODUCT MANUFACTURERS AND SPECIFICATIONS

This appendix contains two sets of tables:

- VMS Installations, listed by manufacturer
- VMS product specifications, listed by sign type.

TABLE D-1. TRAFFIC-RELATED INSTALLATIONS OF VMS, BY MANUFACTURER

MANUFACTURER	INSTALLATIONS
AMERICAN SIGN AND INDICATOR CORPORATION	
BROOKS OPTRONICS (BULB MATRIX)	OUT-OF-MANUFACTURING BUSINESS; MAY BE BOUGHT BY FEDERAL SIGN AND SIGNAL.
DIETZ COMPANY (VEHICLE MOUNTED BULB MATRIX)	USUALLY PURCHASED BY STATE AND MUNICIPAL DOTs FOR MAINTENANCE AND EMERGENCY TRAFFIC CONTROL.
DISPLAY TECHNICIAN CORPORATION (VANE MATRIX)	MOUNTAIN PASS STATUS ADVISORY SYSTEM IN CALIFORNIA; TEMPORARY FOG WARNING SYSTEMS PREVIOUSLY EXISTED IN CALIFORNIA.
FEDERAL SIGN AND SIGNAL (BULB MATRIX).	SANTA MONICA FREEWAY SYSTEM.
FOSCO FABRICATORS (ROTATING DRUMS & SCROLLS)	DRUM SIGN SYSTEMS AT VIRGINIA'S HAMPTON ROADS (33 DRUMS), LAGUARDIA AIRPORT, CHICAGO'S KENNEDY EXPRESSWAY, AND ELSEWHERE; 19 SCROLL SIGNS (ORIGINALLY FURNISHED AND INSTALLED BY 3M) ON I-40 IN NORTH CAROLINA. FOUR BULB MATRIX SPEED LIMIT SIGNS ON I-79 IN PENNSYLVANIA.
INFORMATION CONCEPTS (DISC MATRIX)	TWO SIGNS ON I-80 R.V. SYSTEM IN WYOMING; TWO SIGNS ON PENN LINCOLN PARKWAY IN PITTSBURGH.
RANK PRECISION IND. (FIBER-OPTICS)	TUNNEL APPROACH IN HOLLAND WITH 70 SIGNS; DATA BEING AWAITED.
RHODES AND MAINE, INC. (VEHICLE MOUNTED BULB MATRIX)	SEVERAL UNITS PURCHASED IN CALIFORNIA FOR MAINTENANCE AND EMERGENCY TRAFFIC CONTROL.
TRAFFIC CONTROL SYSTEMS (SCROLL-LIKE)	MOTORIST ADVISORY SYSTEM AT EISENHOWER TUNNEL/LOVELAND PASS, COLORADO; DOES NOT INCLUDE VISIBILITY WARNINGS.
SOLARI (SCROLL)	TOLL ROAD 13 MILES 20.9 KM LONG, NEAR NAPOLI, ITALY PLUS 25 YEARS EXPERIENCE IN AIRPORT, RAILWAY STATION, AND BANK SYSTEMS.
VALTEC CORPORATION	CURRENTLY DEVELOPING VARIABLE MESSAGE FIBEROPTICS SIGN SYSTEM.
VARICOM 3M (HINGED PANEL, MOTORIZED FLAP)	PRIMARILY USED FOR TIME-OF-DAY DISPLAYS OF "NO LEFT TURN" TYPE MESSAGES.

Table D-1. Traffic-Related Installations of VMS, by Manufacturer (Continued)

MANUFACTURER	INSTALLATIONS
VEPED TRAFFIC CONTROLS INC. (HINGED PANEL)	PRIMARY USED FOR TIME-OF-DAY DISPLAYS OF "NO LEFT TURN" TYPE MESSAGES. • ONE SIGN ON I-65 INDIANA FLASHING "FOG" ALTERNATELY WITH "REDUCE SPEED". • SIX SIGNS ON I-75 IN CINCINNATI WITH NUMEROUS PREPROGRAMMED MESSAGES INCLUDING "FOG AHEAD," "CONGESTION AHEAD," ETC. • TWO SIGNS ON I-64 IN KENTUCKY WITH SEVERAL PREPROGRAMMED MESSAGES INCLUDING "FOG AHEAD," "ICE AHEAD," "REDUCE SPEED, " ETC.
WINKOMATIC SIGN COMPANY (BULB MATRIX)	• TWO SIGNS ON NEWPORT BRIDGE, R.I. ROUTE 138 WITH SEVERAL PREPROGRAMMED MESSAGES INCLUDING "FOG AHEAD," "ICE AHEAD," "REDUCE SPEED," ETC. • ONE SIGN ON PENN TNPK. WITH SEVEN PREPROGRAMMED MESSAGES INCLUDING "FOG AHEAD," "ICE AHEAD," "REDUCE SPEED," ETC. • SIX SIGNS ON CHESAPEAKE BAY BRIDGE AND TUNNEL WITH TEN PREPROGRAMMED MESSAGES INCLUDING "FOG AHEAD," "ICE AHEAD," "REDUCE SPEED," ETC. • FOUR SIGNS ON I-95 DELAWARE RIVER BRIDGE WITH TEN PREPROGRAMMED MESSAGES INCLUDING "FOG AHEAD." • VARIABLE SPEED LIMIT SIGNS AT DELAWARE RIVER BRIDGES ON I-80 AND I-95.

TABLE D-2. PRODUCT SPECIFICATIONS BY SIGN TYPE, TABLE A

BULB MATRIX	DISPLAY FACE FORMAT	DISPLAY SIZE*	MESSAGE FORMATS
DIETZ TRAFFIC DETECTOR $10,850 INCLUDING ALL ACCESSORIES	7 BULB X 35 BULB MATRIX MAX. WORD SIZE: 7 LETTERS	16 BY 80 INCHES (41 BY 203).	64 WORDS ARE PREPROGRAMMED. ONE CAN BE DISPLAYED STEADILY, OR UP TO FOUR CAN BE FLASHED SEQUENTIALLY.
RHODES AND MAINE VARI/MATRIX 400 $6,000 – FIVE CHARACTERS, $10,000 – SEVEN CHARACTERS INCLUDING FOUR MESSAGE MODULES, MOUNTING FOR TRUCK AND GENERATOR	5 SEPARATE SINGLE-CHARACTER DISPLAYS OR 7 CHARACTER DISPLAY. 7 BULBS X 5 BULBS PER CHARACTER	8 BY 35 INCHES OR (20 BY 89) OR 15 BY 65 (38 BY 165).	CASSETTE-LIKE MESSAGE MODULES, EACH STORING EIGHT MESSAGES; MAXIMUM MESSAGE IS FOUR WORDS.
FEDERAL SIGN AND SIGNAL FED 3000 ELECTRONIC MESSAGE CENTER	SOLID BULB MATRIX HEIGHT: 7 BULBS/LINE LENGTH: VARIABLE	ONE OR TWO LINES, 30 VARIOUS SIZES, FROM 1 BY 13 FEET (30 BY 396) TO 7 BY 57 FEET (213 BY 1737).	18 TO 40 COMPUTER-STORED MESSAGES. EACH MESSAGE ALLOWS UP TO 87 TRAVELING LETTERS AND 5 STEADY OR FLASHING LINES (SPEEDS VARIABLE). SINGLE OR DOUBLE STROKE LETTERS OR PICTORIALS. AUTOMATIC CENTERING.
WINKOMATIC VM III	SOLID BULB MATRIX HEIGHT: 7 BULBS/LINE LENGTH: VARIABLE	LINE HEIGHT: 12 INCHES (30) OR 15 INCHES (38). OTHER DIMENSIONS ARE UNLIMITED.	MESSAGES CAN BE CONTROLLED BY PUNCHED TAPE, TELEPRINTER, COMPUTER, LOCAL MANUAL CONTROL, ETC.
WINKOMATIC VM 109	SUFFICIENT BULBS TO DISPLAY UP TO 12 PREPROGRAMMED MESSAGES PER LINE	LINE HEIGHT: 12 INCHES (30), 15 INCHES (38), OR 18 INCHES (46). LINE LENGTH IS VARIABLE.	UP TO 12 MESSAGES PREPROGRAMMED FOR EACH SIGN LINE. ANY TWO MESSAGES CAN BE ALTERNATED.
WINKOMATIC VM 110 (VMX-9444)	SUFFICIENT BULBS TO DISPLAY 2 PREPROGRAMMED MESSAGES	LINE HEIGHT: 15 INCHES (38) TWO LINES NEEDED FOR STANDARD FOG MESSAGE, LINE LENGTH: SEVEN FEET (213).	"FOG AHEAD" ALTERNATES WITH "REDUCE SPEED."

*DIMENSIONS WITHIN PARENTHESES ARE IN CENTIMETERS.

Table D-2. Product Specifications by Sign Type, Table A (Continued)

BULB MATRIX	DISPLAY FACE FORMAT*	DISPLAY SIZE*	MESSAGE FORMATS
WINKOMATIC VM 111	SOLID BULB MATRIX (7 BULBS HIGH) + BULBS AT RIGHT AND FOR SPECIAL SYMBOLS	LINE HEIGHT: 12 INCHES (30), 15 INCHES (38) OR 18 INCHES (46). LINE LENGTH IS VARIABLE.	UP TO 12 PRE-STORED MESSAGES AND UP TO 10 NUMERICAL SPEED INDICATION PLUS COLORED LANE USE SYMBOLS.
WINKOMATIC VM 112 (VMS 3036)	"SPEED" BACKLIT PLUS TWO SINGLE CHARACTER DISPLAYS OF SEVEN BULBS BY FIVE BULBS EACH FOR NUMERICAL DISPLAY.	30 BY 36 INCHES (76 BY 91)	"SPEED XX" WHERE "XX" IS A NUMERICAL VALUE BETWEEN 01 AND 99.
FOSCO SENTINEL SIGN SYSTEM $12,000 (INCLUDING INTERNAL LIGHTING, HEATING AND BACKUP POWER SYSTEM).	MESSAGES ARE SILK-SCREENED ONTO TRANSPARENT POLYESTER FILM. INTERNAL ILLUMINATION ENABLES NIGHT TIME VISIBILITY.	57 BY 48 INCHES (145 BY 122)	UP TO 16 MESSAGES PER SCROLL. UNLIMITED COLORS. PICTORIAL MESSAGES EASILY DISPLAYED. MESSAGE CHANGE REQUIRES 1.5 SECONDS PER FRAME.
DISC MATRIX			
INFORMATION CONCEPTS INC. "TELE-SPOT" WYOMING SYSTEM (2 SIGNS) COST: $189,000 (INCLUDING TOTAL SYSTEM INSTALLATION SUPERVISION CHECKOUT	SOLID DISC MATRIX: NUMBER OF LINES AND LINE LENGTH VARIABLE. THREE TO FOUR LINES OF 20 CHARACTERS EACH IS TYPICAL. CHARACTER SIZE IS FIVE DISCS BY SEVEN DISCS. CHARACTER HEIGHT IS TYPICALLY 12 INCHES (30) OR 18 INCHES (46)	TYPICALLY BETWEEN 5 BY 22 FEET (150 BY 67) AND 9 BY 33 FEET (270 BY 1,000)	FLASHED OR STEADY. UP TO 375 STORED MESSAGES. GIANT CHARACTER SET AS WELL AS ASCII AVAILABLE FOR THREE AND FOUR-LINED SIGNS.
VANE MATRIX			
DISPLAY TECHNOLOGY CORPORATION, "DISTEC MODEL III", COSTS ARE NOW BEING DETERMINED BY MANUFACTURERS; SAID TO APPEAR TO BE "VERY COMPETITIVE"	SOLID VANE MATRIX. EACH VANE IS 0.5 INCHES (1.3) SQUARE. CHARACTER SIZE IS VARIABLE.	0.5 BY 5 FEET (15 X 150), 1.5 BY 5 FEET (46 X 150), 1.5 BY 11 FEET (46 X 335), OR CUSTOM BUILT UP TO 8 BY 40 FEET (240 X 1,1220).	UP TO 20 STORED MESSAGES AND GRAPHICS PLUS TYPED-IN MESSAGES. FLASHED OR STEADY.

*DIMENSIONS WITHIN PARENTHESES ARE IN CENTIMETERS.

Table D-2. Product Specifications by Sign Type, Table A (Continued)

BULB MATRIX	DISPLAY FACE FORMAT*	DISPLAY SIZE*	MESSAGE FORMATS
DRUM			
FOSCO "VARIABLE MESSAGE DRUM SIGN" TYPICALLY $7,200 FOR A 2.5 BY 30 FEET THREE-FACED SINGLE DRUM SIGN	ONE OR MORE LINES STACKED HORIZONTALLY OR VERTICALLY. COLORED AND REFLECTORIZED BACKGROUND AND COPY.	ANY SIZE.	TWO, THREE, FOUR, OR SIX-SIDED ROTORS.
WINKOMATIC "ALUMINUM DRUM SIGNS"	STACK DRUMS VERTICALLY FOR ANY SERIES OF MESSAGES COLORED AND REFLECTORIZED BACKGROUND AND COPY.	TYPICALLY 18 FEET (550) LONG WITH A 23 INCH (30) LETTER HEIGHT. OTHER SIZES AVAILABLE.	MULTI-SIDED ROTORS AVAILABLE, FACES EASILY REMOVED FOR MESSAGE CHANGE.
SCROLL			
SOLARI "VARIABLE SIGN INDICATOR, $4,000 TO $,50000	MESSAGES ARE SILK-SCREENED ONTO TRANSPARENT BAND, INTERNAL ILLUMINATION ENABLES NIGHTTIME VISIBILITY.	4 BY 4 FEET (120 BY 120)	UP TO 30 MESSAGES PER SCROLL. UNLIMITED COLORS CAN BE USED. SHIFT TO ADJACENT MESSAGE REQUIRES TWO SECONDS. PICTORIAL MESSAGE EASILY DISPLAYED.
TRAFFIC CONTROL SYSTEMS "VARIABLE MESSAGE SIGN" SMALL MODEL: $8,915; LARGE MODEL: $15,535	TWO LINES, 22 SPACES EACH. 12 INCH (30) OR 18 INCH (46) LETTER HEIGHT. INTERNAL ILLUMINATION ENABLES NIGHTTIME VISIBILITY.	2.5 BY 15 FEET (76 BY 457) OR 3.5 BY 23 FEET (107 BY 700)	SIX PREPROGRAMMED MESSAGES, EASILY CHANGED BY SERVICE PERSONNEL.
HINGED PANEL			
VARICOM "ELECTRO-MECHANICAL CMC" APPROXIMATELY $775 (DEPENDENT ON SIZE AND MESSAGE), INCLUDING CONTROL CABINET	REFLECTIVE SHEETING, HIGH INTENSITY GRADE. STANDARD COLORS.	FEET 2 BY 2.5 (61 BY 76) 2 BY 3 (61 BY 91) 2.5 BY 2.5 (76 BY 76) 2.5 BY 3 (76 BY 91)	TWO MESSAGES MAXIMUM, EACH OF SIMILAR SIZE. CHANGE OF MESSAGE TAKES FIVE SECONDS OR LESS.
VePED "TIME-A-SIGN" $763 EXCLUDING HEATER THERMOSTAT	NONREFLECTIVE OR REFLECTIVE SHEETING. STANDARD COLORS.	FEET 2 BY 2 (61 BY 61) 2 BY 2.5 (61 BY 76) 2.5 BY 2.5 (76 BY 76) 2.5 BY 3 (76 BY 91) 2.5 BY 4 (76 BY 122) 3 BY 3 (91 BY 91) OR CUSTOM SIZES	TWO MESSAGES MAXIMUM, EACH OF SIMILAR SIZE.

*DIMENSIONS WITHIN PARENTHESES ARE IN CENTIMETERS.

TABLE D-3. PRODUCT SPECIFICATIONS BY SIGN TYPE, TABLE B

BULB MATRIX	INSTALLATION	ACCESSORIES AVAILABLE FROM MANUFACTURER	BULB INTENSITY
DIETZ TRAFFIC DETECTOR $10,850 INCLUDING ALL ACCESSORIES	SINGLE AXLE TRAILER FURNISHED BY MANUFACTURER.	CONTROL CABINET, GASOLINE-POWERED GENERATOR.	TWO LEVELS AUTOMATIC.
RHODES AND MAINE VARI/MATRIX 400 $6,000 – FIVE CHARACTERS, $10,000 – SEVEN CHARACTERS INCLUDING FOUR MESSAGE MODULES, MOUNTING FOR TRUCK AND GENERATOR	SUPPORTS FURNISHED BY MANUFACTURER FOR ROOF, TRUCK, TRAILER, OR PERMANENT INSTALLATION.	PROGRAMMER AND MESSAGE MODULES, GASOLINE-POWERED GENERATOR.	THREE LEVELS NOT AUTOMATIC.
FEDERAL SIGN AND SIGNAL FED 3000 ELECTRONIC MESSAGE CENTER	MANUFACTURER IS AVAILABLE FOR TOTAL SYSTEMS MANAGEMENT WORK.	BACKUP POWER SUPPLY.	CONTINUOUS AUTOMATIC DIMMING.
WINKOMATIC VM III	MOUNTING BRACKETS. MANUFACTURER IS AVAILABLE FOR TOTAL SYSTEMS MANAGEMENT WORK.	SOFT-START CIRCUIT.	TWO TO THREE MANUAL LEVELS OR CONTINUOUS AUTOMATIC DIMMING.
WINKOMATIC VM 109	SEE ABOVE.	SEE ABOVE.	SEE ABOVE.
WINKOMATIC VM 110 (VMX-9444)	SEE ABOVE.	SEE ABOVE.	SEE ABOVE.

Table D-3. Product Specifications by Sign Type, Table B (Continued)

BULB MATRIX	INSTALLATION	ACCESSORIES AVAILABLE FROM MANUFACTURER	BULB INTENSITY
WINKOMATIC VM 111	SEE ABOVE.	SEE ABOVE.	SEE ABOVE.
WINKOMATIC VM 112 (VMS 3036)	SEE ABOVE.	SEE ABOVE.	SEE ABOVE.
FOSCO SENTINEL SIGN SYSTEM $12,000 (INCLUDING INTERNAL LIGHTING, HEATING AND BACKUP POWER SYSTEM).	STRÚCTURES ARE AVAILABLE AND MANUFACTURERS CAN PER-FORM TOTAL SIGN SYSTEMS INSTALLATION.	FOUR FLASHING LIGHTS ABOVE MESSAGE, SIGN IS HEATED. BACKUP POWER SYSTEM. COM-MUNICATIONS CONTROL LOGIC AND KEYBOARD ARE AVAIL-ABLE. MOTORIST AID PHONE SYSTEM TIED INTO COMMUNICA-TIONS SYSTEM IS AVAILABLE.	
DISC MATRIX			
INFORMATION CONCEPTS INC. "TELE-SPOT" WYOMING SYSTEM (2 SIGNS) COST: $189,000 (INCLUD-ING TOTAL SYSTEM INSTALLA-TION SUPERVISION CHECKOUT	SUPPORT MAY BE FURNISHED BY MANUFACTURER.	TELEMETRY COMMUNICATIONS SYSTEM, COMPUTER, TELE-TYPE, CRT TERMINAL, FLOOD LIGHTS FOR NIGHT ILLUMINA-TION.	
VANE MATRIX			
DISPLAY TECHNOLOGY CORPO-RATION, "DISTEC MODEL III", COSTS ARE NOW BEING DETER-MINED BY MANUFACTURERS; SAID TO APPEAR TO BE "VERY COMPETITIVE"		TELEMETRY COMMUNICATIONS SYSTEM, KEYBOARD INPUT UNIT, NIGHT LIGHTING.	

Table D-3. Product Specifications by Sign Type, Table B (Continued)

BULB MATRIX	INSTALLATION	ACCESORIES AVAILABLE FROM MANUFACTURER	BULB INTENSITY
DRUM			
FOSCO "VARIABLE MESSAGE DRUM SIGN" TYPICALLY $7,200 FOR A 2.5 BY 30 FEET THREE-FACED SINGLE DRUM SIGN	SIGN SUPPORT STRUCTURES ARE AVAILABLE FROM MANUFACTURER AS WELL AS SYSTEMS CONSULTATION AND CONSTRUCTION SERVICES.	12 VDC POWER BACKUP, TWO WIRE TLEMETRY CONTROL SYSTEM.	
WINKOMATIC "ALUMINUM DRUM SIGNS"	MOUNTING BRACKETS. MANUFACTURER IS AVAILABLE FOR TOTAL SYSTEMS MANAGEMENT WORK.	HEATER THERMOSTAT, RUBBER ICE DEFLECTORS, BATTERY-POWER BACKUP.	
SCROLL			
SOLARI "VARIABLE SIGN INDICATOR, $4,000 TO $,50000	PEDESTAL FOR ROADSIDE OPERATION SUPPLIED.	AMBER FLASHING LIGHTS ATOP SIGN.	
TRAFFIC CONTROL SYSTEMS "VARIABLE MESSAGE SIGN" SMALL MODEL: $8,915; LARGE MODEL: $15,535	MOUNTING BRACKETS.	SOCKETS FOR ATTACHING FLASHING LIGHTS AVAILABLE. BACKUP INTERNAL LIGHTING SYSTEM; BLANKOUT; BACKUP POWER SYSTEM AVAILABLE.	
HINGED PANEL			
VARICOM "ELECTRO-MECHANICAL CMC" APPROXIMATELY $775 (DEPENDENT ON SIZE AND MESSAGE), INCLUDING CONTROL CABINET	SIGN FRAME AND MOUNTING HUB FURNISHED.	24-HOUR TIMER.	
VePED "TIME-A-SIGN" $763 EXCLUDING HEATER THERMOSTAT	MOUNTING POSTS AND BASES.	24-HOUR TIMER, HEATER THERMOSTAT, AMBER LIGHTS WITH FLASHER.	

Appendix E

CHARACTERISTICS OF COMMUNICATIONS MODULATION EQUIPMENT AND MANUFACTURERS DIRECTORY

This appendix lists characteristics of modulation equipment by system type, and manufacturers of the available systems.

TABLE E-1. CHARACTERISTICS OF MODULATION EQUIPMENT

TYPE OF SYSTEM	CAPACITY		POWER CONSUMPTION	DISTANCE WITHOUT REPEATERS MILES (KM)	COST	EASE OF MAINTENANCE	NOISE IMMUNITY	ERROR DETECTION ABILITY
	DATA POINTS PER CHANNEL	CHANNELS PER PAIR	TRANS/RCVR (WATTS)		RCVR/ TRANS ($)			
DC	1	1	0.25	3 (4.8)	200	EXCELLENT	VERY GOOD	NO
FDM (AM) / FDM (FSK)	1	18	0.240 / 0.180 / 0.150 / 0.480	10 (16.1)	110 / 120 / 175 / 265	VERY GOOD	FAIR / VERY GOOD	NO
TDM SCANNER (SAMPLING)	8 TO 11	18	.420/1.4	10 (16.1)	500/700	GOOD	VERY GOOD	YES
TDM SUPERVISORY (POLLED)	8	UP TO 62 LOCATIONS PER PAIR		10 (16.1)	25,000 PLUS 500 PER LOCATION	FAIR	VERY GOOD	YES

COMMENTS

DC: CAPACITY CAN BE INCREASED BY SACRIFICING DISTANCE. POWER IS ONLY REQUIRED AT THE CENTRAL LOCATION.

FDM (AM) AND FDM (FSK): TRANSMISSION DISTANCE CAN BE INCREASED BY USING LESS CHANNELS/MI. POWER SUPPLIES ARE REQUIRED IN THE FIELD AND AT THE CENTRAL LOCATION (15 W SUPPLY COSTS $160).

TDM SCANNER (SAMPLING): TRANSMISSION DISTANCE CAN BE INCREASED BY USING FEWER CHANNELS PER MILE. POWER SUPPLY IS REQUIRED IN THE FIELD AND AT THE CENTRAL LOCATION. DATA RATE CAPABILITY IS INSUFFICIENT FOR DETECTORS.

TDM SUPERVISORY (POLLED): POWER CONSUMPTION DEPENDS UPON THE NUMBER OF REMOTE SITES AND FORMATTING REQUIREMENTS. COST IS SIGNIFICANTLY LOWER IF PROCESSOR IS AVAILABLE FOR CODING AND DECODING.

TABLE E-2. MANUFACTURERS DIRECTORY

MANUFACTURER	ADDRESS	TYPE OF SYSTEMS				USERS
		FDM	TDM-SCAN	TDM-SUPV	MICRO-WAVE 960 MHz	
RFL INDUSTRIES	BOONTON, NEW JERSEY	●		●		WASHINGTON, DC: UTCS; ATLANTA, GEORGIA: TRAFFIC CONTROL; NEW JERSEY TURNPIKE AUTHORITY: ATS BIRMINGHAM, ALABAMA AND DALLAS, TEXAS
QEI INC.	SPRINGFIELD NEW JERSEY	●	●	●		VIRGINIA DEPARTMENT OF HIGHWAY AND TRANSPORTATION: AFTON MOUNTAIN FOG GUIDANCE SYSTEM; NEW YORK: TRI-BOROUGH BRIDGE AND TUNNEL AUTHORITY; STATE OF ILLINOIS: EXPRESSWAY SURVEILLANCE; WASHINGTON DC: HIGHWAY DEPARTMENT
DATAMASTER	WATERBURY CONNECTICUT	●	●			NEW ORLEANS, LOUISIANA
TREPAC CORP.	ENGLEWOOD, NEW JERSEY	●				
REPCO, INC.	RESTON VIRGINIA				●	
CARDION ELECTRONICS	WOODBURY NEW YORK				●	WYOMING HIGHWAY DEPARTMENT; MINNESOTA HIGHWAY DEPARTMENT; FLORIDA DEPARTMENT OF TRANSPORTATION; STATE OF ARIZONA DEPARTMENT OF PUBLIC SAFETY
TERRACOM	SAN DIEGO, CALIFORNIA				●	
SONEX				●		MEMPHIS, TENNESSEE; WINSTON SALEM, NORTH CAROLINA
GRANGER ASSOCIATION	MENLO PARK, CALIFORNIA			●	●	GREENSBORO, NORTH CAROLINA
LARSE	PALO ALTO, CALIFORNIA	●	●	●		
BRAMCO	PIQUA, OHIO	●	●			MICHIGAN DEPARTMENT OF TRANSPORTATION FOR DETROIT FREEWAY
MOTOROLA	FRANKLYN PARK, ILLINOIS				●	NEW JERSEY TURNPIKE AUTHORITY
EAGLE SIGNAL	AUSTIN, TEXAS			●		LINCOLN, NEBRASKA; SEATTLE, WASHINGTON; TOLEDO, OHIO
TRAFFIC DATA SYSTEMS	COLORADO SPRINGS, COLORADO			●		CHICAGO, ILLINOIS
COMPUTER SYSTEMS ENGINEERING	NORTH BILLERCIA, MASSACHUSETTS			●		MINNEAPOLIS, MINNESOTA
AUTOMATIC DEVELOPMENT COMPANY	INGLEWOOD, CALIFORNIA			●		BELLEVUE, WASHINGTON

Appendix F

VARIABLE MESSAGE SIGN (VMS) USER COMMENTS

This appendix tabulates VMS user comments by installation site, and the typed contents of a computer printout of the message capability of disc matrix signs on the I-80 RVG system in Wyoming.

TABLE F-1. VMS USER COMMENTS TABULATED BY INSTALLATION SITE

SYSTEM LOCATION	VARIABLE MESSAGE SIGN	REPORTED MAINTENANCE EFFORT
I-65; INDIANA	ONE WINKOMATIC LAMP MATRIX SIGN	VERY LITTLE MAINTENANCE EFFORT
I-40; NORTH CAROLINA	19 FOSCO SCROLL SIGNS ORIGINALLY INSTALLED BY 3M	VERY HIGH MAINTENANCE EFFORT[1]
ROUTE 60; FLORIDA	TWO LOCALLY MANUFACTURED NEON SIGNS	LOW MAINTENANCE EFFORT
I-75; OHIO	SIX WINKOMATIC LAMP MATRIX SIGNS	ACCEPTABLE MAINTENANCE REQUIREMENTS
I-64; KENTUCKY	TWO WINKOMATIC LAMP MATRIX SIGNS	HIGH BULB BURN-OUT RATE
NEWPORT BRIDGE; RHODE ISLAND	TWO WINKOMATIC LAMP MATRIX SIGNS	LOW TO MEDIUM MAINTENANCE EFFORT
CHESAPEAKE BAY BRIDGE; VIRGINIA	SIX WINKOMATIC LAMP MATRIX SIGNS	LOW MAINTENANCE AFTER ORIGINAL CORRODED EQUIPMENT WAS REPLACED WITH STAINLESS STEEL
I-95; DELAWARE TO NEW JERSEY	FOUR WINKOMATIC LAMP MATRIX SIGNS	LOW MAINTENANCE EFFORT – ONLY AN OCCASIONAL BULB BURN-OUT IN SEVEN TO EIGHT YEARS OF OPERATION
I-80; WYOMING	TWO ICI DISC MATRIX SIGNS	AVERAGE MAINTENANCE PROBLEMS. STICKY DISCS; EXCESSIVE WIND PRESSURE ON PLEXIGLASS SIGN FACE; DOOR-LOCKING PROBLEMS
I-5; OREGON	SIX LOCALLY MANUFACTURED NEON SIGNS	GENERALLY AVERAGE MAINTENANCE; SOME LOCAL PROBLEMS WITH ACCESS MECHANISMS DUE TO CORROSION
I-8, I-10; ARIZONA	40 WINKOMATIC ROTATING DRUM SIGNS	FAIRLY HIGH MAINTENANCE EFFORT PARTLY RELATED TO MICROWAVE PATH PROBLEMS; ELECTRONICS CIRCUITRY PROBLEMS DUE TO EXCESSIVE HEAT
I-64; VIRGINIA	ONE WINKOMATIC BULB MATRIX SIGN	COMMUNICATIONS CONSISTENTLY A PROBLEM; MAINTENANCE REQUIREMENTS HIGH
ROUTE 91; CALIFORNIA	RHODES AND MAIN TRUCK-MOUNTED BULB MATRIX SIGNS	AVERAGE MAINTENANCE PROBLEMS; ELECTRONIC MODULES SERVICED BY MANUFACTURER
I-495; NEW JERSEY TURNPIKE	38 BULB MATRIX SPEED LIMIT SIGNS 38 NEON TUBING SPEED WARNING SIGNS 57 WINKOMATIC ROTATING DRUM SIGNS	

NOTES

[1] FOSCO, RECENT PURCHASER OF 3M's SCROLL SIGN BUSINESS, IS ATTEMPTING TO REMEDY THE NORTH CAROLINA SIGN PROBLEMS.

Appendix G

ADDRESSES OF MANUFACTURERS/DISTRIBUTORS

G-1 VISIBILITY DETECTION AND MEASUREMENT EQUIPMENT

- AEG Telefunken. One River Rcad, Building 36-444, Schenectady, New York 12305
- AERAZUR Constructions Electroniques. 14, Rue Leon Gambetta - 92120, Montrouge, France
- SATT Elektronik AB. Stockholm, Sweden (product distributed by NAVORR Ltd., 41 Horner Avenue, Toronto, Ontario, Canada)
- ASEA. Vasteras, Sweden
- Ateliers de Constructions Electriques de Chaleroi, SA, Belgium
- B.E.L. Developments Limited. Apex House, Davis Road, Chessington, Surrey, England
- Colorado Electro-Optics. P.O. Box 3034, Boulder, Colorado
- EG&G, Environmental Equipment Division. 151 Bear Hill Road, Waltham, Massachusetts
- Eltro GmbH. Gesellschaft für Strahlungstechnik, 6900 Heidelberg, Postfach 520, West Germany
- FF Impulsphysics Corp., 4632 Vincennes Blvd., Cape Coral, Florida 33904
- Impulsphysik GmbH. 2 Hamburg 56, West Germany
- Hamamatsu Corporation. 120 Wood Avenue, Middlesex, New Jersey 08846
- International Laser Systems, Inc. 3403 N. Orange Blossom Trail, Orlando, Florida 32804
- Lear Siegler, Inc., Environmental Technology Division. 3480 Greenbriar Parkway, SW No. 214, Atlanta, Georgia 30331
- Marconi Radar Systems. New Parks, Leicester, England LE3 1 UF
- Meisal Electric Company. No. 5-7, 2-chome Koishigawa, Bunkyo-Ku, Tokyo, Japan
- MRI, Inc. Altedena, California 91001

- Schlumberger (Compteurs Schlumberger). Div. Instruments et Systemes, Dept. Equipments, 1 Rue Nieuport - BP 54, 7 81 40 Velize-Villacoublay, France

- SIAP. P.O. Box 296, 40100 Bologna, Italy

- Snecma. Elecma Electronics Div., 22 quai Galliene, 92 Suresnes, France

- Photobell Company, Inc. 12 East 22nd Street, New York, New York 10010

- The Plessey Company, Ltd. Plessey Radar, Addlestone, Waybridge, Surrey, England

- Tasker Industries. Los Angeles, California 90039

- Weather Measure Corporation. P.O. Box 41257, Sacramento, California 95841

- McGraw Edison Company. New Providence, New Jersey.

G-2 MANUFACTURERS OF CCTV SURVEILLANCE EQUIPMENT

- Cohn, Inc. Electronics Division, San Diego, California

- General Electric. Microwave and Imaging Devices, Building 7, Electronics Park, Syracuse, New York 13201

- Hamamatsu TV Company, Ltd. 120 Wood Avenue, Middlesex, New Jersey 08846

- Motorola, Communications and Electronics Inc., 1301 E. Algonquin Road, Schaumberg, Illinois 60172

- RCA, Electro Optics and Devices. Solid State Division, Lancaster, Pennsylvania 17604

- Sony Corporation of America. 47-47 Van Dam Street, L.I. City, New York 11101

- Lake Systems. Newton, Massachusetts.

G-3 MANUFACTURERS OF VEHICLE DETECTORS

- Automatic Signal & Indicator, Division of LFE Corporation. Regent Street, East Norwalk, Connecticut 06856
- Canoga Controls. 21609 Parthenia Street, Canoga Park, California 91304
- Decatur Electronics. 715 Bright Street, Decatur, Illinois 62522
- Eagle Signal. 8004 Cameron Road, Austin, Texas
- Enerco. Seattle, Washington
- Fosco Fabricators, Inc. P.O. Box 200 TR, Dixon, Illinois 61021
- Gammatronix. 66 South High Street, Dublin, Ohio 43107
- Indicator Controls. Gardena, California
- Sarasota Engineering. 1500 North Washington Blvd., Sarasota, Florida 33577
- Streeter-Amet. 157 Wicks Street, Grayslake, Illinois 60030
- Traffic Data Systems. 100 E. Commerce Street, Colorado Springs, Colorado 80903

G-4 MANUFACTURERS OF VARIABLE MESSAGE SIGNS

- American Sign and Indicator Corporation. North 2310 Francher Way, Spokane, Washington 99206, (509)535-4101
- Crouse-Hinds Company. Syracuse, New York 13201
- Dietz Company. 225 Wilkinson Street, Syracuse, New York 13201
- Display Technology Corporation (DISTEC). 160 Main Street, Los Altos, California 94022, (415) 948-7391
- Federal Sign, Division Federal Signal Corporation. 5018 Chase Street, Downers Grove, Illinois 60515, (312) 852-7770
- Ferranti-Packard, LTD. Electronics Division. 121 Industry Street, Toronto, Ontario M6M 4M3, Canada
- Fishback & Moore, Inc., Heath Company. 4703 Bengal Street, Dallas, Texas 75235
- FOSCO Fabricators, Inc. P.O. Box 200, Dixon, Illinois 61021, (815) 288-1441

- Information Concepts, Inc., 592 Fifth Avenue, New York, New York 10036 (212) 869-8181

- Rank Precision Industries, Inc., Leeds LTD. In the U.S., can contact Mr. Sedhvanion (914) 358-4450

- Radar Safety Controls Company, Inc., 20 Republic Road, North Billerica, Massachusetts 01862

- Rhodes & Maine, Inc., 824D East Walnut Avenue, Fullerton, California 92631

- Solari America, Inc., 45 West 45th Street, New York, New York 10036 (212) 581-4480

- Traffic Control Systems Company. 2903 Delta Drive, Colorado Springs, Colorado 80910 (303) 392-4228

- Valtec Corporation. West Boylston, Massachusetts 01583 (617) 835-6082

- Varicon 3M, Traffic Control Products Division. 3M Center, St. Paul Minnesota 55101 (312) 496-6500

- Ve-Ped Traffic Controls, Inc., 11313 N. Broadway, Rt. 2, Box 33, Oklahoma City, Oklahoma 73114 (405) 751-5151

- Winkomatic Signal Company. 659 Miller Road, P.O. Box 155, Avon Lake, Ohio 44012 (216) 933-2122

G-5 MANUFACTURERS OF POST-MOUNTED AND ROADWAY DELINEATORS

- Amerace Corporation, Signal Products Division. 7542 North Natchez Avenue, Niles, Illinois

- Cataphote Division, Ferro Corporation. P.O. Box 2369, Jackson, Mississippi

- Hawkins-Hawkins Company, Inc., 1255 E. Shore Highway at Gilman, Berkeley, California

- Lanco Industries of Columbus. P.O. Box 20229, Columbus, Ohio 45220

- Proven Products. 7560 SW Lakeview Drive, Portland, Oregon 97219

- Transpacific Equipment Corporation. 1901 Avenue of the Stars, Los Angeles, California

- Zumar Industries, Inc., 2828 Stanford Avenue, Los Angeles, California

- 3M Safety Systems Division, 3M Center. Building 223-3N, Department 45, St. Paul, Minnesota

G-6 MANUFACTURERS OF COMMUNICATION COMPONENTS AND SYSTEMS

DATA COMMUNICATIONS

- C-COR. 60 Decibel Road, State College, Pennsylvania 16801
- Datamasters (Bristol Division of ACCO) 40 Bristol Street, Waterbury, Connecticut 06720
- Harris Corporation. Melbourne, Florida 32901
- Interactive Systems. 3980 Varsity Drive, Ann Arbor, Michigan 48104
- RFL Industries, Inc. 6 Powerville Road, Boonton, New Jersey 07005
- Sonex, Inc. 2337 Philmont Avenue, Bethayres, Pennsylvania 19006
- Tele-Measurements. 145 Main Avenue, Clifton, New Jersey 07014
- Traffic Data Systems. 100 E. Commerce Street, Colorado Springs, Colorado 80903
- TOCOM. 3301 Royalty Row, Tyler, Texas

HIGHWAY ADVISORY RADIO

- Audio-Sine, Inc.
  3415 Forty-eight Avenue, North
  Minneapolis, Minnesota 55429
  - Systems (whip antenna)
- CSI Electronics, Inc.
  3800 So. Congress Avenue
  Boynton Beach, Florida 33435
  - Systems (cable/whip)
- Halsted Communications, Inc.
  22 East 40 Street
  New York, New York
  - Cable Radiator
- Loc Rad, Inc.
  5707 Lady Lane
  Tucson, Arizona 85704
  - Systems (cable)
- Morad Company
  Seattle, Washington
  - Whip antenna
- Montedoro-Whitney Corporation
  P.O. Box 1401
  2740 McMillan Road
  San Luis Obispo, California 93401
  - Systems (cable/whip)

- Nautical Maine, Inc. - Systems
  Building 278
  Florida Avenue, BIA
  Bangor, Maine 04401

- Telline Radio - Systems
  6630 Electronic Drive
  Springfield, Virginia 22151

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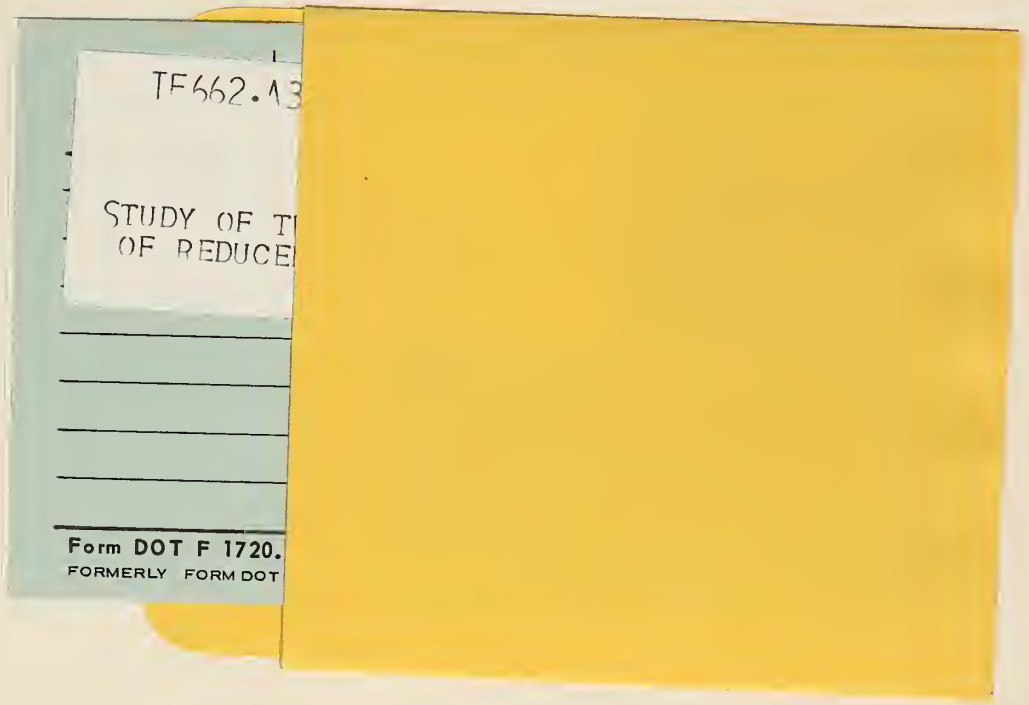
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FEDERALLY COORDINATED PROGRAM OF HIGHWAY RESEARCH AND DEVELOPMENT (FCP)

The Offices of Research and Development of the Federal Highway Administration are responsible for a broad program of research with resources including its own staff, contract programs, and a Federal-Aid program which is conducted by or through the State highway departments and which also finances the National Cooperative Highway Research Program managed by the Transportation Research Board. The Federally Coordinated Program of Highway Research and Development (FCP) is a carefully selected group of projects aimed at urgent, national problems, which concentrates these resources on these problems to obtain timely solutions. Virtually all of the available funds and staff resources are a part of the FCP, together with as much of the Federal-aid research funds of the States and the NCHRP resources as the States agree to devote to these projects.*

FCP Category Descriptions

1. Improved Highway Design and Operation for Safety

Safety R&D addresses problems connected with the responsibilities of the Federal Highway Administration under the Highway Safety Act and includes investigation of appropriate design standards, roadside hardware, signing, and physical and scientific data for the formulation of improved safety regulations.

2. Reduction of Traffic Congestion and Improved Operational Efficiency

Traffic R&D is concerned with increasing the operational efficiency of existing highways by advancing technology, by improving designs for existing as well as new facilities, and by keeping the demand-capacity relationship in better balance through traffic management techniques such as bus and carpool preferential treatment, motorist information, and rerouting of traffic.

3. Environmental Considerations in Highway Design, Location, Construction, and Operation

Environmental R&D is directed toward identifying and evaluating highway elements which affect the quality of the human environment. The ultimate goals are reduction of adverse highway and traffic impacts, and protection and enhancement of the environment.

4. Improved Materials Utilization and Durability

Materials R&D is concerned with expanding the knowledge of materials properties and technology to fully utilize available naturally occurring materials, to develop extender or substitute materials for materials in short supply, and to devise procedures for converting industrial and other wastes into useful highway products. These activities are all directed toward the common goals of lowering the cost of highway construction and extending the period of maintenance-free operation.

5. Improved Design to Reduce Costs, Extend Life Expectancy, and Insure Structural Safety

Structural R&D is concerned with furthering the latest technological advances in structural designs, fabrication processes, and construction techniques, to provide safe, efficient highways at reasonable cost.

6. Prototype Development and Implementation of Research

This category is concerned with developing and transferring research and technology into practice, or, as it has been commonly identified, "technology transfer."

7. Improved Technology for Highway Maintenance

Maintenance R&D objectives include the development and application of new technology to improve management, to augment the utilization of resources, and to increase operational efficiency and safety in the maintenance of highway facilities.

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* The complete 7-volume official statement of the FCP is available from the National Technical Information Service (NTIS), Springfield, Virginia 22161 (Order No. PB 242057, price $45 postpaid). Single copies of the introductory volume are obtainable without charge from Program Analysis (HRD–2), Offices of Research and Development, Federal Highway Administration, Washington, D.C. 20590.

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